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VERTICAL ARRAY CALIBRATION PROFILER DESIGN DESCRIPTION

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SUMMARY

This document presents a detailed hardware and operational description of the Vertical Array Calibration Profiler. This apparatus is used to calibrate the vertical array. The vertical array is one of two eight element arrays in the Experimental Array Radar System (EARS). It has eight standard gain horns oriented in a vertical line using horizontal polarization. This report presents a short description of the EARS and how the vertical array and VACP are used in the system. The VACP is described in detail, beginning with a general description and continuing with more detailed information.

This document was prepared under task 6.3 of contract number W7714-5-9868. It covers a gap in the system documentation. The VACP was designed and built by the Communications Research Center (CRC) under guidance from Applied Silicon personnel. There has been no previous formal documentation written about it.

The calibration procedure for the vertical array is described, along with the use of the VACP as part of this procedure. Preliminary calibrations of the vertical array and the calibration software used are also described.

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1.0 INTRODUCTION

This document is a complete design description of the Vertical Array Calibration Profiler (VACP) system. The VACP is used for one phase of the vertical array calibrations. It is used to determine the exact phase front arriving at the reflector of the vertical array. It was found in 1994 that the calibrations of the vertical array done by the manufacturer were inadequate and inaccurate. The VACP is the result of the effort to provide accurate calibration data for the vertical array.

Of the two eight element arrays that are used in the Experimental Array Radar System (EARS), the vertical array is the more difficult one to calibrate. The Side-Lobe Canceller (SLC) array uses a horizontally oriented row of horns which point directly at the target of interest. The vertical array also uses eight horns which are oriented in a vertical row. However, the horns receive the target of interest returns indirectly, after they have been reflected by a large cylindrical parabolic reflector. This reflector is used to add gain to the signals. It is the indirect reception of signals that causes problems for the calibration. The presence of the reflector makes it impossible to introduce a constant known calibration signal into each horn pair of the vertical array. A previous report, "Calibration of Ears Horizontal and Vertical Arrays - Functional Requirements Document" provides detailed information on calibrating the vertical array, including a review of how the manufacturer did it and why their calibration data cannot be used. This report was written before the VACP was integrated, but most of the information it contains on the vertical array calibration is still applicable. It is assumed that the reader has some familiarity with the EARS and the information contained in the previous calibrations document.

2.0 EARS DESCRIPTION

The EARS is an experimental radar system used for research into several areas including target height estimation, target tracking, main beam nulling and side-lobe nulling. It has been developed for over ten years and has gone through several major phases. It is based at a remote site of the Defence Research Establishment Ottawa (DREO) called 'Area Five', which is located on the Ottawa River. Figure One is a block diagram of the EARS front end. It has two eight element receiving arrays, the Vertical Array and the SLC, or Horizontal, Array. Each array produces 60 MHz intermediate frequency (IF) signals which are processed by two similar IF receivers. The down-converted IF receiver outputs are digitized at 20 megasamples per second and stored on a 13 gigabyte hard disk array. A ten meter long portable lab houses the 'back end' of the system. The system 'front end' is contained on a rack which is mounted on a turntable. The direction of the antennas is adjustable in azimuth with the turntable, but not in elevation. Twenty meter cables connect the two main parts of the system. The received RF signals are down-converted to the 60 MHz IF by mixers before they are sent to the lab over the long RG58 coaxial cables.

A front end unit called the Exciter is the source of the transmitted X-band signal and the local oscillator (LO) signals. It contains a highly accurate and stable 10.0 MHz oscillator which is used as the EARS base clock. All RF, IF and timing signals are phase locked to this source. The SLC array is mainly mounted on a single large plate, located near the top of the front end rack. The

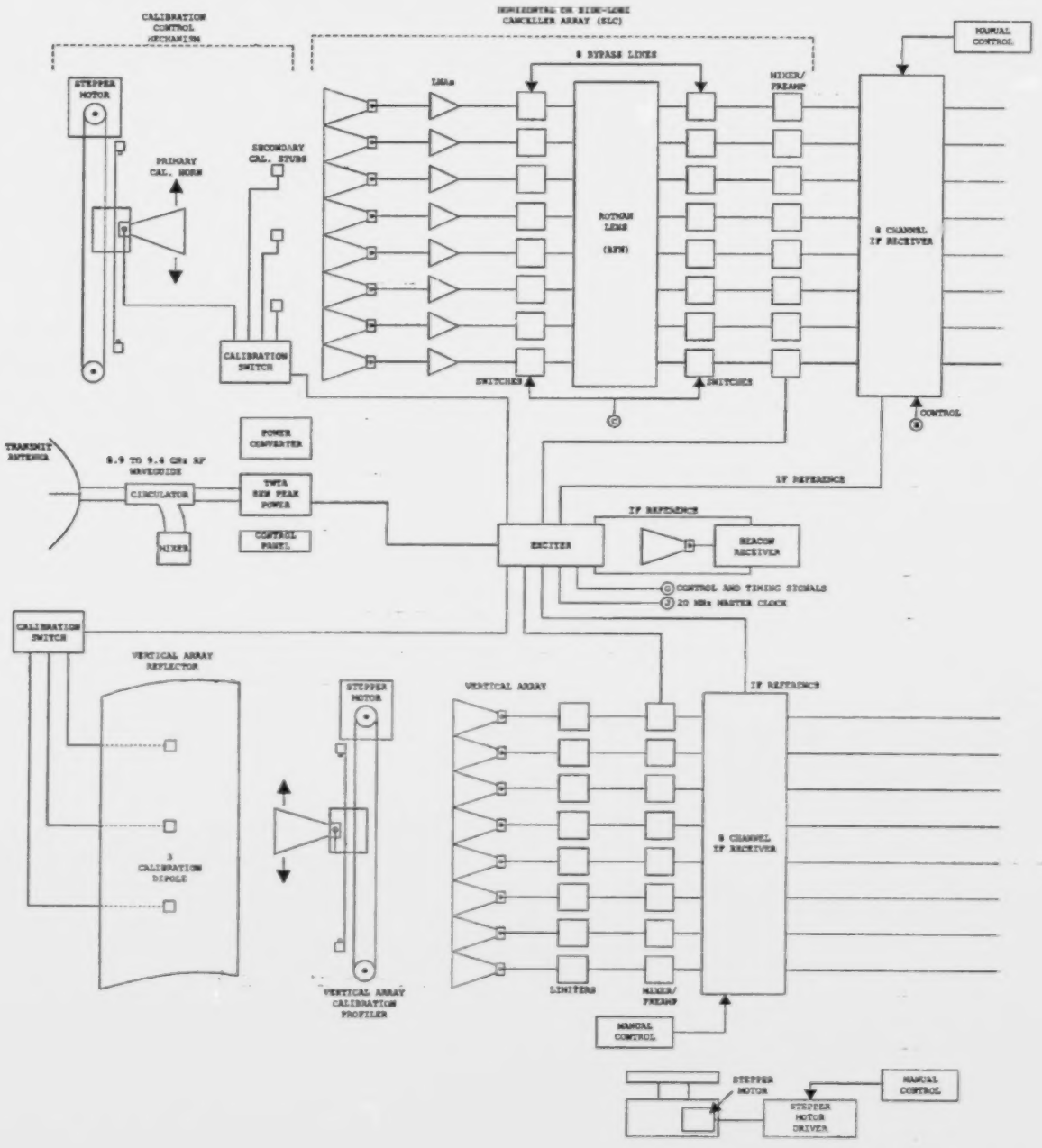

Figure 1

EARS Front End Block Diagram

receiving horns are mounted on the CCM frame, directly ahead of the plate. Semi-rigid coaxial cables connect the horn outputs to the array low noise amplifiers (LNA).

The vertical array was first integrated when the EARS was known as the Experimental Low Angle Tracking (ELAT) system. The ELAT system used two 65 kilowatt peak power magnetrons and had a coherent on receive setup. The EARS is coherent on transmit since all the signals are phase locked to the 10 MHz source. A travelling wave tube amplifier (TWTA) amplifies the 8.90 to 9.40 GHz signal produced by a synthesizer in exciter. It is rated at eight kilowatts peak power. The EARS pulses the transmitted signal at a pulse repetition frequency (PRF) of 500 hertz to 25 kilohertz. The pulse widths are from two microseconds down to 200 nanoseconds.

3.0 VACP GENERAL PHYSICAL DESCRIPTION

Figures two, three and four are various views of the VACP. These figures were produced by the designer, Rob Macey of the CRC. They show the VACP affixed to the vertical array frame in its operational position. The stepper motor and gear train enclosure are missing from these three diagrams. The drive belt, limit switches, lower gear assembly and cabling are also missing. The motor enclosure is mounted at the top of the vertical track, behind the track and beside the vertical array frame.

The VACP basically consists of a small standard gain horn which is mounted on a moving carriage. The carriage rides on a precisely built and positioned vertical track. This track is exactly parallel to the surface and vertical edge of the vertical array reflector. Two clamps are used to hold the VACP in place, with respect to the reflector. They wrap around the closest vertical frame member directly behind the outer edge of the reflector. No holes have been drilled through the frame member, so its structural integrity is not compromised. Each mount uses two large pieces of threaded rod. Each rod has four nuts to allow the track to be aligned with the reflector. After the alignment was done, holes were drilled through the nuts and wires were fed through the holes to prevent any movement.

The vertical track is long enough so the horn can be positioned at any point along the reflector from its bottom edge to its top edge. The track is constructed of a central piece of milled aluminum with special hard stainless steel 'V' shaped tracks running along each side. The horn carriage has four metal complementary 'V' shaped wheels that ride on the two hard tracks. The tracks and wheels are made with very small tolerances so there is no play or looseness between the carriage and the tracks. The carriage moves easily on the tracks and keeps the horn pointed in the same direction over the entire track length. Figure four shows the wheels and tracks best, from above.

A drive system was added to the VACP shortly after it was initially designed. A small stepper motor moves the horn carriage via a gear train and drive belt. The stepper motor and gear train are contained in an enclosure at the top of the VACP. Limit switches are positioned at each end of the travel extent to stop the motor and prevent damage if it goes too far.

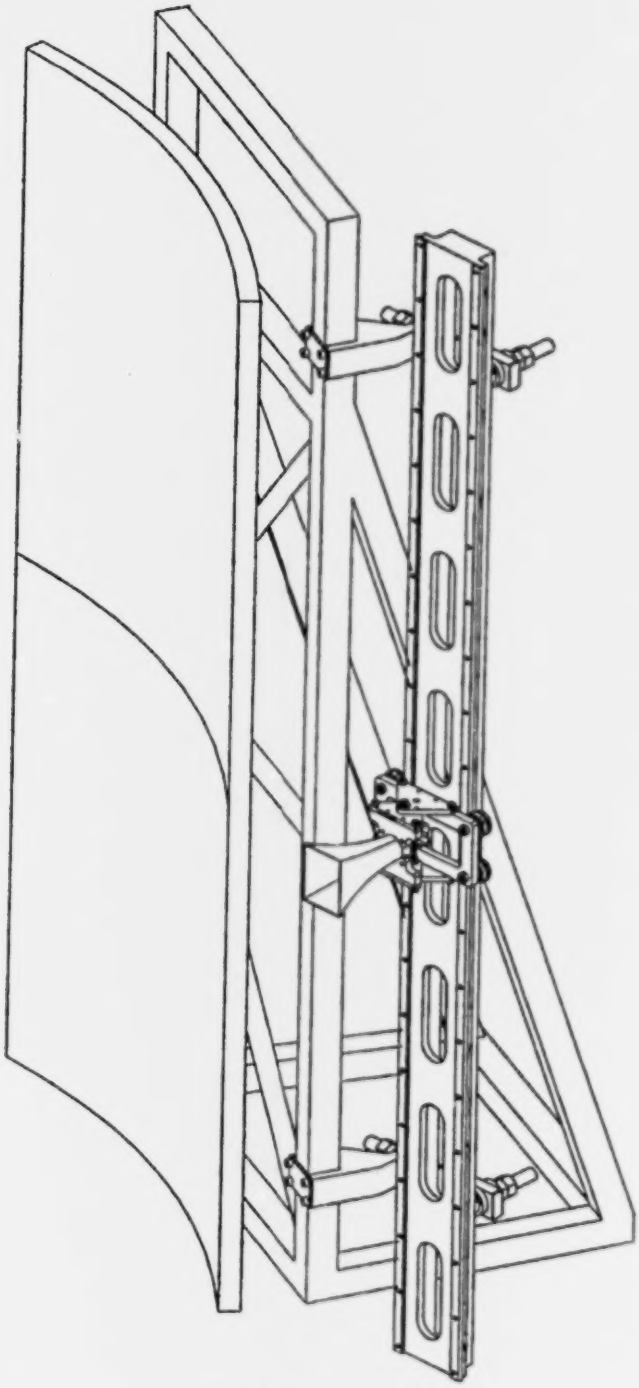

Figure 2

Pictorial View of VACP Mounted on Vertical Array

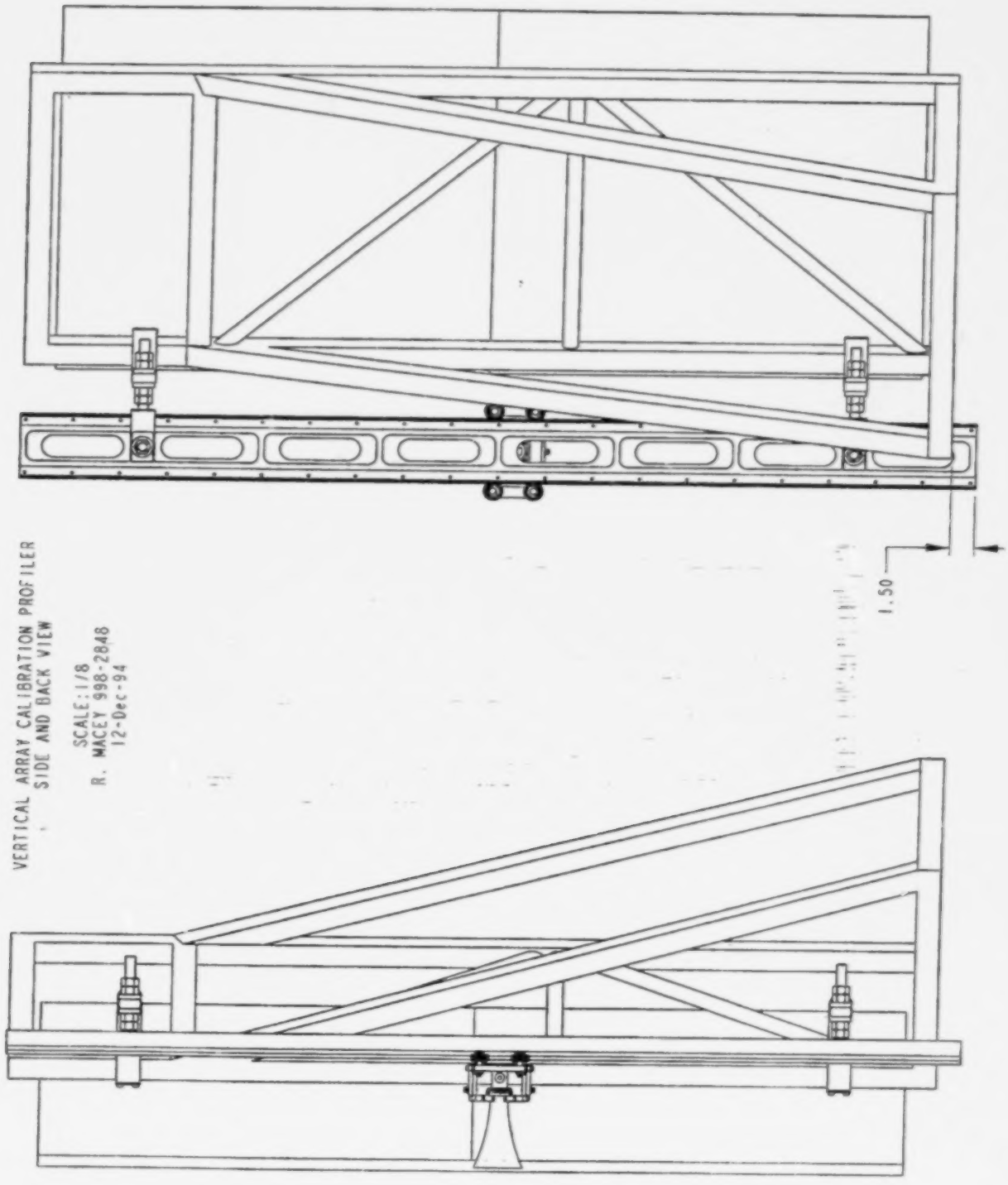

Figure 3

Side and Back Views of VACP on Vertical Array

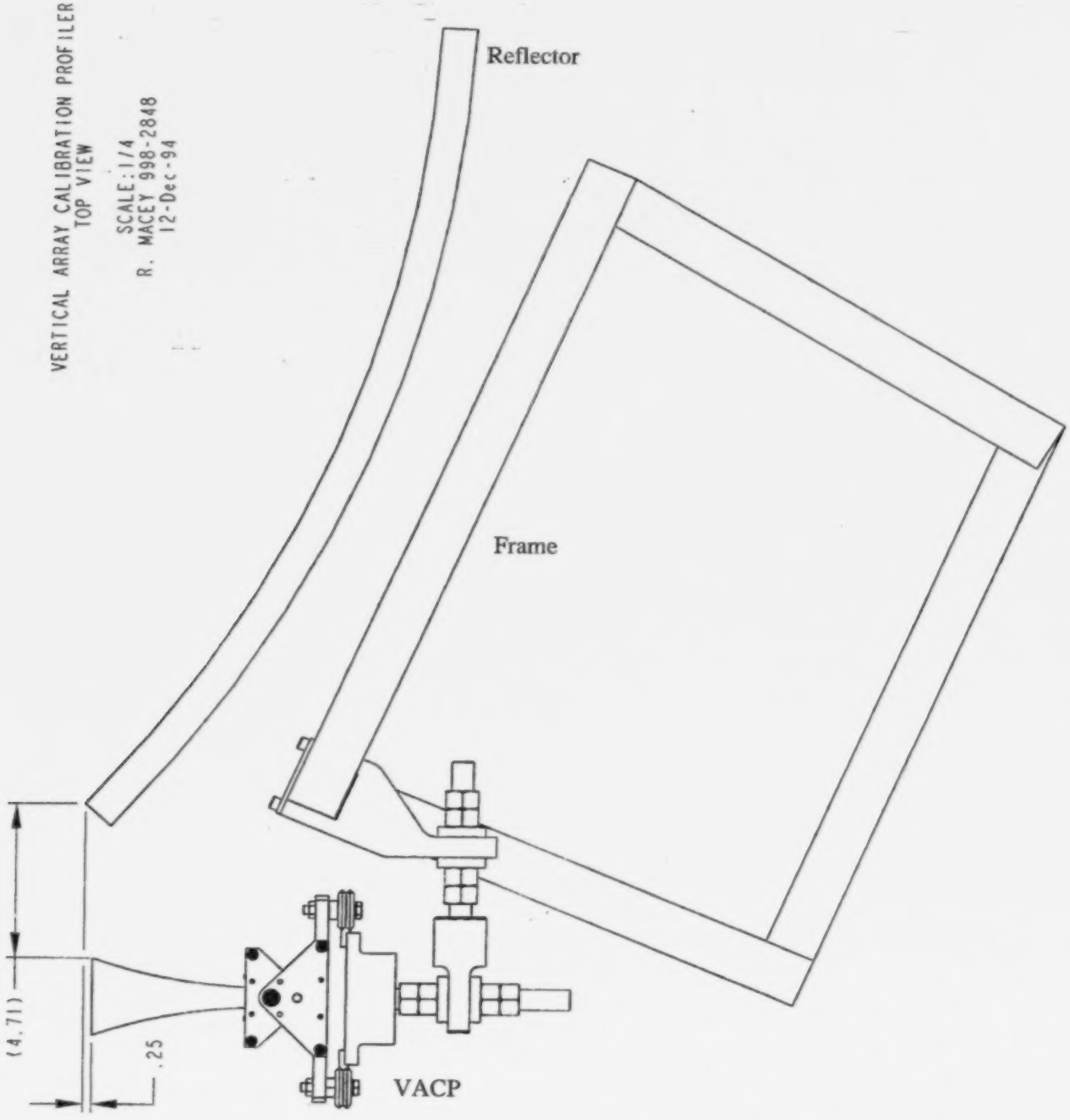

Figure 4

Top View of VACP on Vertical Array Frame

4.0 VACP DETAILED HARDWARE DESCRIPTION

This section provides descriptions of each major part of the VACP. The VACP was designed in December 1994. It was built and integrated onto the vertical array in early 1995. At that time it did not have a stepper motor. The horn carriage was moved by hand and secured in place using a spring loaded pin. A corresponding pin hole was drilled in the center section at each horn position. This was an accurate and repeatable method of positioning the carriage, however, it was slow and cumbersome. After some practice using the VACP it was decided a stepper motor should be added to make it more user friendly and shorten the time required to do a calibration. It was removed from the vertical profiler and taken back to the CRC for the design and integration of the stepper motor and drive system. The motorized version of the VACP was put back on the vertical array in the summer of 1995.

4.1 Stepper Motor Controller and Driver

The stepper motor controller, driver, power supply and motor were originally purchased as a package from CyberResearch Inc. It was the low-cost single motor size 23 system, number CMCS 021A. It consists of the following parts;

ESH 5001	single axis stepper motor controller board
INST 339A	37 pin screw terminal block with cable
SMD 102	40 volt, 2 amp bi-polar chopper driver (IMS part number IB462)
ORM 266E	size 23 stepper motor
MPS 28-02	28 volt, 2 amp power supply

This system was assembled and tested as a stand-alone unit. During the design of the VACP is was realized that more torque might be needed, so the SMD103 (IMS part number IB463) driver was purchased to replace the SMD102. The manual for these drivers has been included in appendix A. The power for the driver is supplied by the main front end power supply, rather than the MPS28-02 power supply. A separate connector was added to the power supply for the required 24 volts to the driver. The INST339A was only used during the stand-alone testing and is not part of the VACP.

The ESH5001 controller board connects to the eight bit ISA bus in any standard PC. It has a 37 pin D shell connector for the connections to the motor driver. A custom shielded cable has been made to connect the controller board to the driver. The signal levels output from the controller card are TTL level, including the pulse, direction and hold signals. The controller accepts the two limit switch inputs and will stop the pulse outputs if a limit switch closure is detected for the direction of travel that is in operation. The board comes with test software which allows simple movements and control of the register contents.

The ESH5001 contains a set of eight bit registers. These registers are addressed and written to indirectly as input/output ports on the PC. The registers are loaded with the appropriate numbers for the next motor movement and then a command is sent to begin the movement. A status register

contains a bit that is high only when the motor is in motion. The registers contain the values for the number of steps to move, the starting low speed, the acceleration, the high speed, the deceleration, the ramping down point, the rate multiplier and the output mode selection.

The control software written for the VACP is described in section 6.0 and the software listing is included in appendix B. The SMD103 driver can be controlled by any compatible controller, providing the sequencing and timing of the pulses meet its requirements. The stepper motor does not even require the SMD103 to drive it. Any other compatible driver can be used instead. At present, control of the VACP and the data collection is done as a stand-alone unit. It would be much better if the control could be supplied by the system controller. A VME based controlled card could replace the ESH5001 controller and interface with the SMD103, or a new driver could also be used. This is what has been done to control the Calibration Control Mechanism (CCM) for the horizontal array.

4.2 Stepper Motor and Drive System

The Vexta PH264 E1.5 (CyberResearch ORM264E) stepper motor is used in the VACP. It can supply enough torque and is the smallest NEMA size 23 motor available. It has a peak torque of about 50 oz-in from 1000 to 2000 pulses per second and a holding torque of 40 oz-in. It is used in full step mode for a step size of 1.8 degrees, or 200 steps per revolution. A special solid shaft coupling connects it to the gear train.

A gear train consisting of four gears is used to multiply the torque to the final belt drive gear. The gear train is contained inside the motor enclosure for protection, however, the final belt drive gear is outside the enclosure. The entire drive system was designed by Rob Macey of the CRC Design Office. He chose the gear ratios according to the required drive torque, drive speed and the capabilities of the 264 stepper motor. There is no provision for position feedback and a shaft encoder was not designed into the drive system.

4.3 Standard Gain Horn

The receive antenna used on the carriage is the same type of antenna used on the SLC array. It is the Narda model 640 standard gain horn. It is mounted to receive a horizontally polarized signal, the same polarization used with both EARS arrays. A standard SMA connector waveguide to coaxial transition is used at the horn output. This horn has an isotropic gain of about 15.2 decibels at nine gigahertz. The carriage is designed to rigidly hold the horn level, so there is no allowance for adjustment in elevation. The horn mount is vertically pivotted, so there is a wide range of adjustment in azimuth. It has been adjusted so its peak amplitude response is in the same direction as the boresight of the vertical array reflector. This is shown is figure 4. The beamwidth of this horn is very broad, so it could actually be aimed up to about ten degrees off the reflector boresight without causing any problem.

4.4 Receiver

The VACP horn receives a signal from a remote beacon source. The level at the horn input must be high enough to keep the signal significantly above the noise level of the receiver, but not so high as to saturate any receiver components. There are only two active components in the receiver, as shown in figure 5. The coaxial line from the horn transition goes to 27J3 on the VACP receiver enclosure. The cable is a special flexible coaxial cable made by Flexco Microwave, model 52214-40004-048. It is made to be very flexible, but not affect the signal significantly. It can flex down to a coil of three inches diameter. Over the X-band, the phase change due to the cable flexing is much less than one degree and the amplitude stability is typically less than 0.05 decibels. Internally the flexible cable connects to the RF input of the mixer/preamp, model DM8-12/10A by RHG Labs. This mixer down-converts the signal to the 60 MHz IF, using a local oscillator from the exciter. The same LO signal also goes to the range tracking receiver, after going through a two-way splitter to divide it equally between the two receivers. The mixer IF output is fed to an amplifier, the ICFT 6010 by RHG Labs, via a three decibel in-line attenuator. The amplifier has a fixed gain of about 35 decibels. The IF output goes to the vector analyzer input via connector 27J4. To date, the vector analyzer is the only device that has been used to digitize and measure the received IF signal. In the future, a separate ADC and logger may be used.

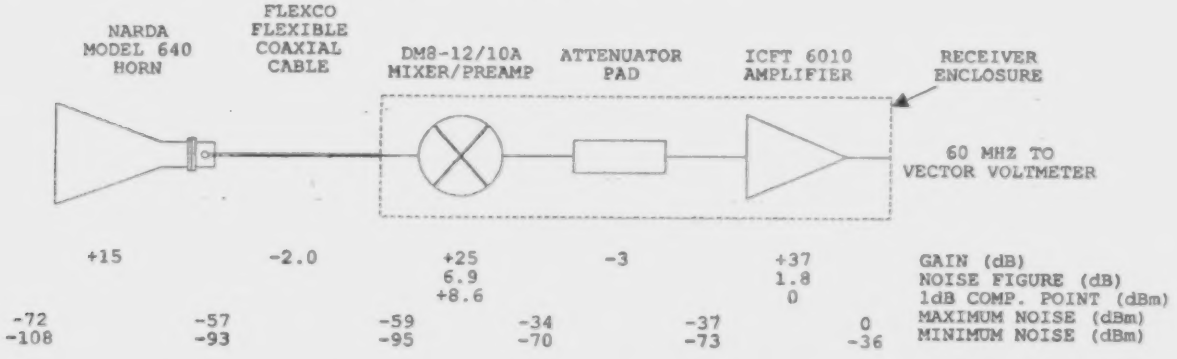

Figure 5 - Block Diagram of VACP Receiver

The receiver mixer and amplifier are physically mounted inside an enclosure which is affixed to the rear plate on the vertical array, directly behind the array reflector. This enclosure was a preliminary version for the beacon receiver, but it could not be used for that purpose. It does, however, work well for the VACP receiver enclosure.

Figure 5 is a block diagram of the VACP receiver, from the horn through to the 60 MHz output, which is intended as the vector voltmeter input. It summarizes some of the information explained in the following report sub-sections.

4.4.1 Receiver Bandwidth

The receiver bandwidth is limited by the narrowest bandwidth device in the receiver chain. There are two bandwidth specifications to consider. The first is the RF bandwidth due to the minimum and maximum RF signals that can be received. In the current EARS configuration, this is restricted to the 500 MHz bandwidth that is transmitted from the TWT. The instantaneous bandwidth at any given transmit frequency is determined by the individual receiver components. The narrowest bandwidth component determines the overall instantaneous bandwidth of the receiver. Both the mixer and amplifier have specified three decibel bandwidths of 10 megahertz. They each have a tested bandwidth of 14 MHz. All the other receiver components used in the VACP have a much wider bandwidth than this, therefore, the instantaneous receiver bandwidth is 14 MHz.

4.4.2 Receiver Noise Floor and Noise Figure

The noise figure of the IF amplifier is much lower than the noise figure of the mixer/preamp, therefore, its contribution to the receiver noise figure is negligible. The noise figure of the receiver is approximately 6.9 dB, depending on the exact frequency.

To calculate the output noise of an active RF device, the following formula is used;

$$\text{Noise Out} = N_o = F\,k\,T_o\,B_n\,G$$

where F = linear noise figure
k = Boltzman's Constant = 1.38×10^{-14} mW/°K·MHz
T_o = temperature in Kelvin = 273 K + 20°C = 293 K
B_n = bandwidth in megahertz
G = linear Gain

For the mixer/preamp the linear noise figure is 4.898, the bandwidth is 14 MHz and the linear gain is 316. Putting these figures into the above equation yields a noise output of 8.77×10^{-8} mW, or -70.6 dBm. Reducing this by three decibels, due to the in-line attenuator at the output of the mixer/preamp, gives a noise input to the amplifier of -73.6 dBm.

The noise generated by the amplifier at its input is defined as $N = k\,T_o\,B_n$. The amplifier has a bandwidth of 14 MHz, therefore, its input noise is -102.5 dBm. This is much lower than the noise output of the mixer/preamp. When the noise from the mixer/preamp is amplified by 37 dB, the final receiver noise output becomes -36.6 dBm.

4.4.3 Receiver Dynamic Range

The dynamic range of a receiver system is defined as the difference between the maximum output signal level and the minimum detectable signal level. The maximum level is determined by the one decibel compression point of the active devices. The minimum useful signal level is the

level that can just be detected above the system noise floor. In a properly designed front end the noise floor is usually determined almost entirely by the noise in the first active device. This has been shown to be the case in the VACP receiver. The IF amplifier has a one decibel compression point of 0 dBm. The noise output from it, due almost entirely from the mixer/preamp, is -36.6 dBm. Therefore, the useful dynamic range of the VACP receiver is about 36 decibels. When the maximum output signal is transferred back to the horn input, a maximum input level of about -72 decibels can be received without driving the receiver into saturation. This is a rather high level and would never be realized with any practical beacon source located at the desired range of at least five kilometers.

As shown on figure 5, the smallest signal that can be received is about -108 dBm at the horn input. This is assuming the signal is at the same level as the equivalent input noise. This is valid when using some data averaging. If no averaging is used, the signal must usually be about three decibels above the noise floor to be recognized. When a greater amount of averaging is used, the minimum useful signal level is lowered considerably.

5.0 INTERCONNECTIONS

Figure 6 is a block interconnection diagram of the VACP. Appendix D contains the detailed interconnection information. It is the same list found in the interconnection document. Figure 6 is basically self-explanatory. The nomenclature used in appendix D is explained at the end of the list. The motor driver has two six position terminal strips, so there is no real connector for it.

6.0 VACP OPERATING PROCEDURE

The VACP is used during step one of a four step calibration process for the vertical array. A document was written in December 1994, "Calibration of EARS Horizontal and Vertical Arrays - Functional Requirements Document" that covered the entire calibration process in great detail. It was written before the VACP was constructed, however, most of the procedures in this document are still applicable and have been used recently, with some refinements. The calibration step that uses the VACP will be described, although for greater detail the reader should refer to the previous calibrations document.

Figure 7 is a block diagram which shows the equipment setup required to use the VACP for calibration of the vertical array. A far field beacon, at a range of at least five kilometers, is required. During the recent calibrations the 'silo source' has been used. It is at a range of 13.5 kilometers but it provides a strong CW signal which is suitable for reception by the VACP. The HP8508 vector voltmeter is used to digitize and average the 60 MHz IF signals. It requires a reference input into channel A. All the phase measurements are then made with respect to the reference. The IF output of the beacon receiver is used for the vector voltmeter reference. It is passed through a limiting amplifier which is in the exciter. This limiting amplifier produces a constant amplitude output over a wide 60 MHz input amplitude range.

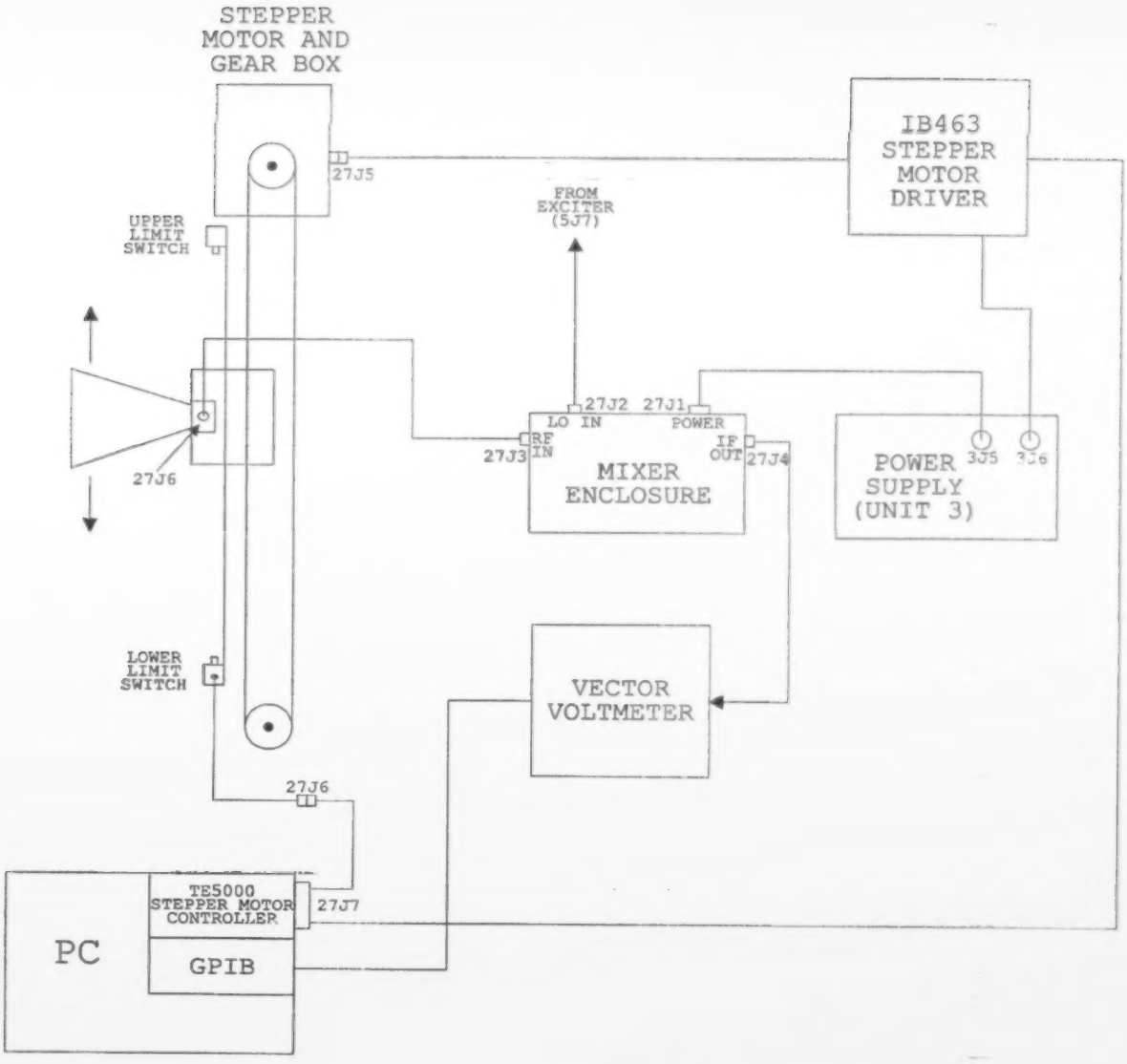

Figure 6

VACP Interconnection Block Diagram

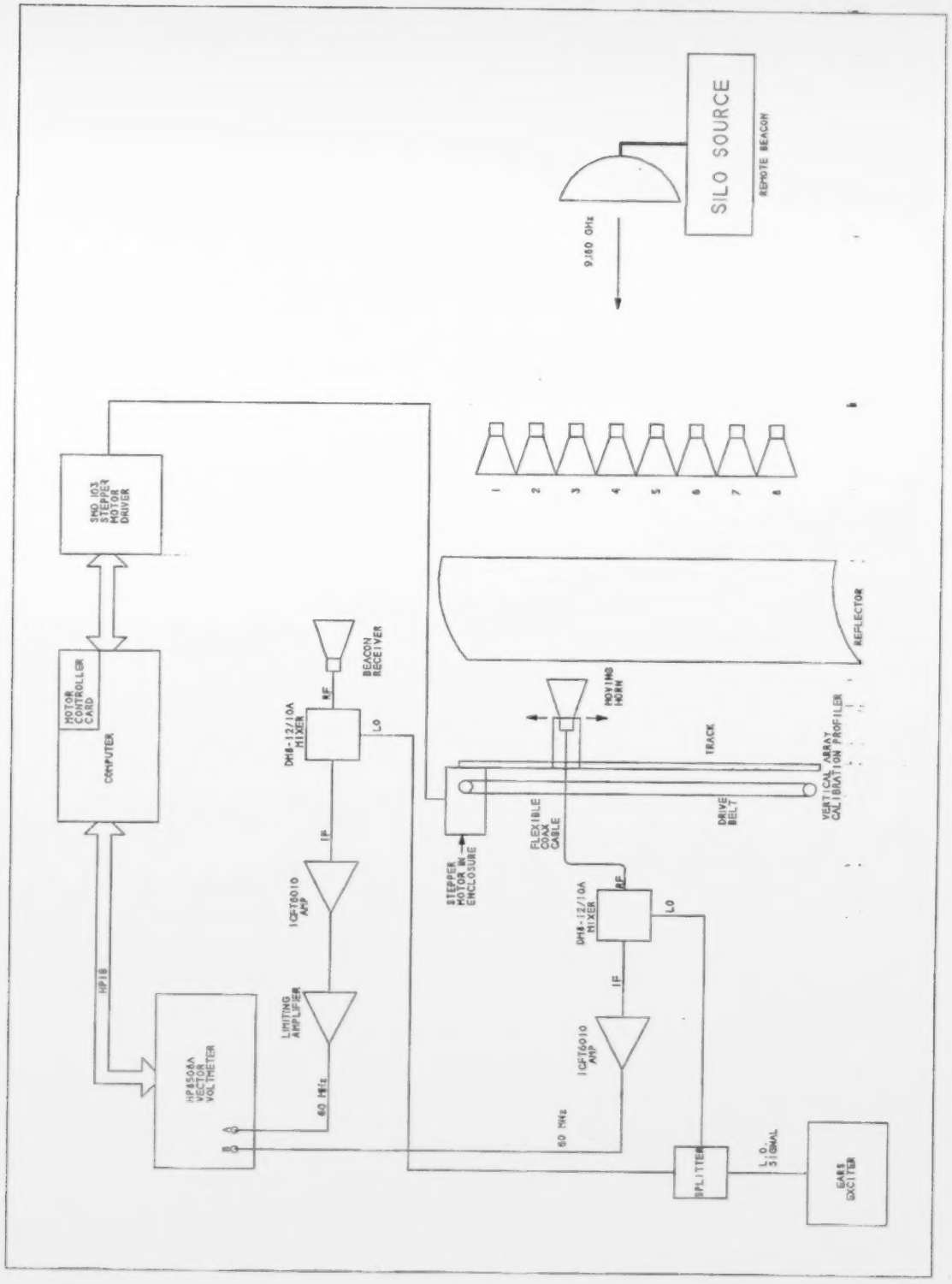

Figure 7
Vertical Array Calibration Setup Using VACP

A computer is used to control the calibration procedure using the VACP and to log the data. It communicates with the vector voltmeter via the GPIB. It initializes, sets up and commands the vector voltmeter to take the data. It also requests the averaged data which is then logged into a file on the hard disk. A stepper motor controller card, as described in section 4.1, is interfaced to the computer via the internal ISA bus. It is connected to the external stepper motor driver, the SMD103, and supplies the timing and control signals to it.

The calibration procedure using the VACP has been refined by experimentation. Several programs have been written for the control PC although the latest program, called VACPCAL3.BAS, was used for the recent vertical array calibrations. It is a BASIC program and runs using the GWBASIC interpreter. Its complete listing is included in appendix B. The procedure for the use of the VACP will be described by describing the operation of the VACPCAL3 program.

Once the calibration setup has been put together as shown in figure 7 and is checked for operation the large door on the tall bay building is opened. An oscilloscope is used to check the strength and quality of the received IF signals from the silo source. If the signals are acceptable then the calibration procedure is continued. The best time to do a vertical array primary calibration is during the winter when there is ice on the Ottawa River. The day should be calm, without precipitation and preferably close to zero degrees Celsius. The environment has a large influence on the signals from the far field beacon source. The more stable the environment is, the better. The entire calibration procedure should be conducted in as little time as possible, so the environment does not have a chance to change significantly over the calibration period.

When the VACPCAL3 program is run, some brief instructions are shown on the computer monitor. The power to the SMD103 stepper motor driver should be disabled. The horn carriage is then moved slowly by hand to the start position near the top of the track. It must not be forced to move too quickly or damage to the gear system or drive train could result. The carriage is moved to the upper-most horn position. The pin should easily go into the horn one hole when the position is correct. Remove the pin and enable power to the stepper motor driver. The operator then enters the data file name. This is done on program line number 170.

Program lines 180 to 290 initialize the GPIB, and then set up the vector voltmeter to take 64 readings and average them using a bus trigger. The file is opened at line 300. Lines 310 to 440 comprise the main program loop. This loop is executed eight times, once for each horn position. From line 330 to line 350 the vector voltmeter is commanded to take the data and transfer the averaged data to the computer. Lines 360 to 410 pick out the channel A amplitude, channel B amplitude and phase from the ASCII data stream and assign them to the appropriate variables. The variables are then displayed on the monitor, sent to the printer and sent to the data file. The operator is prompted at line 420 to press the enter key to move to the next horn position. A subroutine is called to actually move the horn. When the main loop counter reaches 8, the last horn position has been done and the loop finishes. The carriage is then moved back to the start position by calling the move subroutine from line 470.

The subroutine at line 520 moves the carriage one horn position down. It initializes the stepper motor controller. The registers are then written to for the move parameters such as the number of steps to move, the starting low speed, the acceleration, the high speed, the deceleration, the ramping down point, the rate multiplier and the output mode selection. The motion is started at line 1190. A short loop is then entered which reads the controller status port and detects the state of the pulse output active bit. It continually monitors this bit until it goes low, indicating the end of the movement. The subroutine then returns to the calling code.

The subroutine from *line 1250 to line* 1980 is very similar to the move subroutine at line 520, except it moves the carriage from the horn one position at the bottom back up to the start horn eight position at the top. Once this is done the program is exited back to the BASIC interpreter after closing the data file. It takes less than one minute to execute the seven moves down and the one move back up. Line 420 can be removed if it is not necessary to get an input from the operator to make the next move. This will speed up the execution.

The data file consists of eight sets of readings, one for each horn position. At each position the reference channel amplitude, the received amplitude and the phase difference between the two is recorded in ASCII format. This file can then be read by a plotting program to plot the phase and amplitude pattern over the horn positions. Appendix C contains four sample plots showing the channel phases over several days. It can be seen that all the phase curves are approximately the same shape and parallel, except for one the first data taken on 9 April. The absolute phase differences between each curve occur due to changes in the environment and the temperature of the equipment.

7.0 VERTICAL ARRAY CALIBRATIONS

During February, March and April of 1996 much work was done using the VACP. Many calibration data files were collected and plotted. The most significant plots are included in Appendix C. The VACP was used over many days, with several runs on each day, to study the effect of the environment and the time the system was powered on the phases. It is much more important and difficult to calibrate the phase rather than the amplitude. These calibrations are covered in another report, "EARS Acceptance Tests and Calibration Document", therefore, the procedures and results concerning the VACP will only be briefly reviewed here.

The VACP worked well over the entire calibrations period. It did not return the horn carriage back to the exact start position after each run. This was probably because the wrong number of steps was used in the program to go back to the start. This was remedied by manually moving the carriage back to the start position after each run. The system was powered on for at least one hour before data was collected on any day. Typically four to six runs were made on each day, with about one to two hours between each run. This was to determine how the phases changed throughout the day due to the environment or variable equipment temperatures. The runs taken on 7 March use the filenames M07VP-A to M07VP-D, with the last letter indicating the order of the run, with 'A' coming first. The plots taken on March 7, 15 and 26 are shown in appendix C.

It was expected that the phase plots would appear as near linear over the eight positions, with possibly a very slight curvature. This is almost exactly what happened. The curves were very consistent over any given day and between the days. The only real changes that occured were constant frequency shifts, however, these shifts affected each channel by the same amount. These were caused by the environment or possibly by the warming of the equipment. Runs were made with the VACP during the melting and breakup of the river ice. It was found that the more open water there was, the more variable the curves became. This can be seen in the four runs taken on 9 April, with filenames A09VP-A to A09VP-D. This result confirmed the initial comment that the calibrations are best done while the ice is on the river and the environment is the most stable.

APPENDIX A

MANUFACTURER'S DATA SHEETS

IMS™

INTELLIGENT MOTION SYSTEMS

IB462/IB463

MINIATURE HIGH PERFORMANCE
BIPOLAR STEPPING MOTOR DRIVES

OPERATING INSTRUCTIONS

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8. APPLICATION INFORMATION

1 INTRODUCTION

Congratulations! You are now the proud owner of a high performance, miniature, single chip, stepping motor drive. The IB462 and IB463 are high power, bipolar chopper drives capable of delivering up to 160 and 280 watts. Each unit has an input voltage of up to 40 volts. This coupled with a per phase current of up to 2 and 3.5 amps allows the IB462 and IB463 to answer the needs of a wide variety of todays high performance stepping motors.

Features of the IB462 and IB463 include a single power supply, a 22 khz chopping rate, and optically isolated inputs. Inputs include half/full step, direction, step clock, output enable, and current control. The most amazing feature of the IB462 and IB463 is their size. The IB462 measures only 1.25 X 2.375 X 2.9 inches while the IB463 is 1.25 X 2.9 X 2.9 inches. This small size, along with their standard .045 square pins, make these units ideal for PC board mounting. Both these units, however, can be frame or chassis mounted and will accept .200 center connectors or plug type terminal strips.

2 THEORY OF OPERATION

The IB462 and IB463 are bipolar chopping stepper motor drives. They receive step clock, direction, and mode signals from the system controller and generate constant phase currents which are adjustable in magnitude.

The principal functions are : optical isolation to isolate system supplies and signals from the motor supply which is typically noisy, a translator which generates the motor phase sequences, a dual PWM chopper circuit which regulates the current in the motor windings, and a power stage to drive the motor. The translator generates three different sequences selected by the half/full step input. These are normal (two phases energized), wave drive (one phase energized) and half step (alternatly one phase energised/ two phases energized).

A common on-board oscillator drives the dual chopper. It supplies pulses which set two flip-flops. When the current in a winding reaches the programmed peak value a corresponding comparator resets its flip flop, shutting down the output stage until the next oscillator pulse comes along. Because the windings in the motor store

energy, current will continue to flow through the windings during the off period. The peak current for both windings is programmed by the current adjust input.

The output stage consists of dual full bridge drivers. Both drives can be disabled by a high signal on the enable input. Ultra fast recovery flyback rectifiers are used to improve efficiency and help reduce noise.

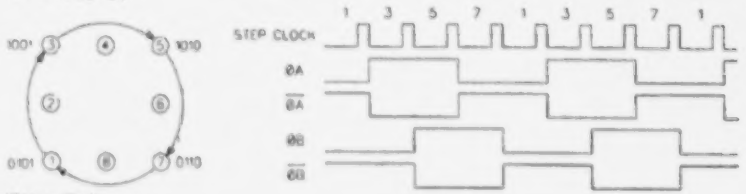
The input isolation circuit is shown in fig. 2. High gain optocouplers are used to decrease the input current needed for switching. The optocouplers allow the system controller to be electrically isolated from the motor supply. This removes the high current switching noise from control system.

3 OUTPUT PHASE SEQUENCES

The IB462 and IB463 generate phase sequences for normal, wave, and half step modes. The state diagram and output waveforms are shown below. In all modes the transition occurs on the falling edge of STEP CLOCK.

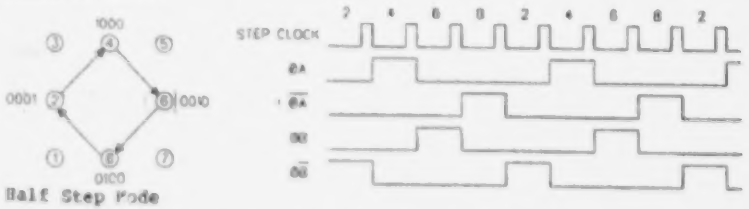
Normal Mode

In normal drive mode two phases are energized at all times. This mode is selected by selecting FULL when the IB462 and IB463 are in an odd numbered state. On power up the IB462 and IB463 initialize to state 1.



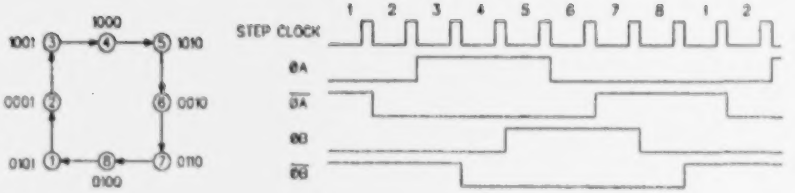
Wave Mode

In wave drive mode one phase is energized at a time. This mode is selected by selecting FULL when the IB462 and IB463 are in an even numbered state.



Half Step Mode

In half step mode the phasing alternates from one phase energized to two phases energized. Half step mode is selected by a low on the half/full step input.

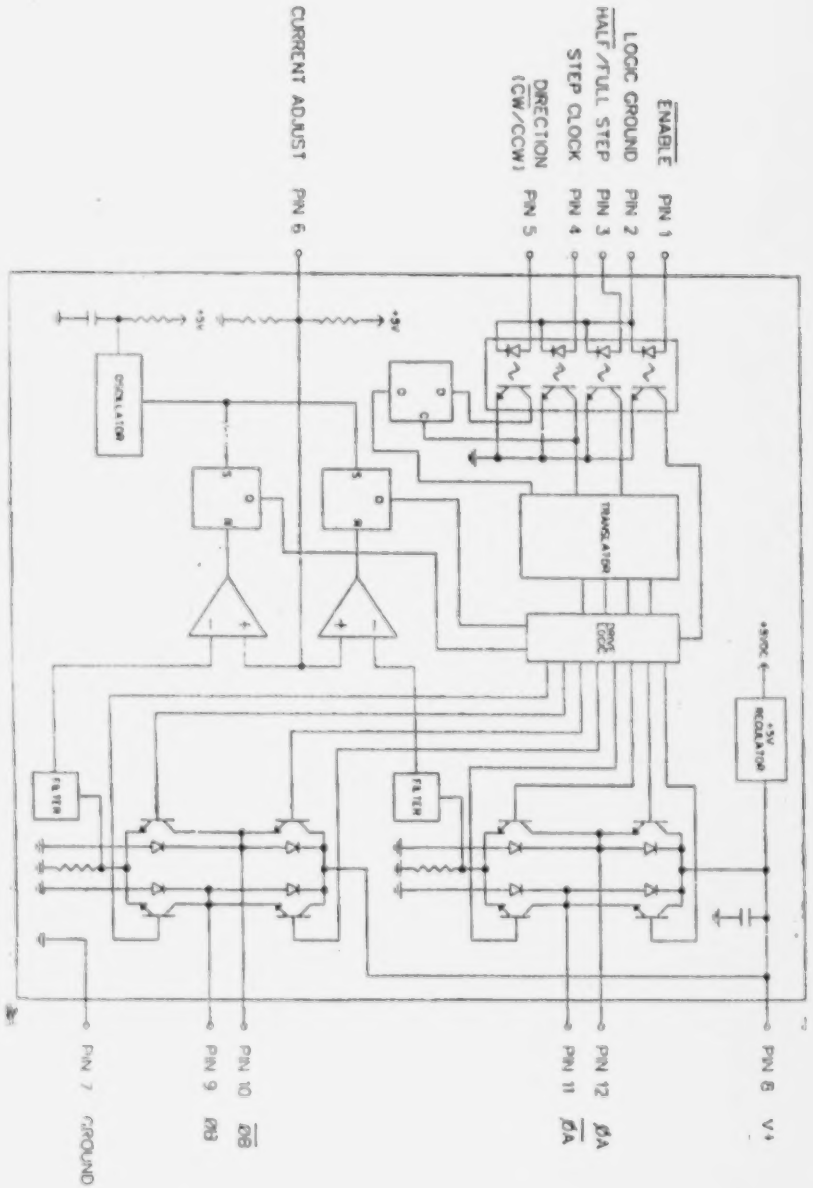


4 ELECTRICAL SPECIFICATIONS

T_A = 25 °C , V+ = 40v

	Test Condition	IB462 min.	IB462 typ.	IB462 max.	IB463 min.	IB463 typ.	IB463 max.	units
V+ Input Voltage		12		*40	12		*40	V
I Input Current				2			3.5	A
I_q Quiescent Current	Outputs Floating		75			90		mA
V_{ce} sat (h) Source Saturation Voltage	I_l = 2A		1.8	2.6		1.7	2.4	V
V_{ce} sat (l) Sink Saturation Voltage	I_l = 2A		1.7	2.4		1.6	2.3	V
BV_r Input Reverse Breakdown Voltage				5			5	V
V_f Input Forward Voltage	I_f = 1.6 mA		1.5	1.75		1.5	1.75	V
I_f Input Current			6.3	15	5	6.3	15	mA
T_{clk} Step clock Pulse width		3			3			uS
T_s Set up time ($\overline{CW}$/CCW & $\overline{H}$/F)		2			2			uS
T_h Hold time ($\overline{CW}$/CCW & $\overline{H}$/F)		5.5			5.5			uS
F_c Commutation Frequency				40			40	kHz

* The maximum input voltage with the output disabled is V_{max} +10 %.



ABSOLUTE MAXIMUM RATINGS

	IB462	IB463	
Input Voltage	10 to 45		V
Phase Current	2	3.5	A
* Case Temperature	80		°C
Storage Temperature	-40 to +125		°C
I_F Average Input Current (each channel)	15	15	(1) mA
Peak Input Current (each channel) (50% duty cycle, 1mS pulse width)	30	30	mA
V_F Reverse Input Voltage (each channel)	5		V
Input Power Dissipation (each channel)	35		(2) mW

* Additional cooling may be necessary to limit case temperature to 70 °C.

Note: 1. Derate linearly above 50°C case temperature at a rate of 0.5 mA/°C for the IB462.
2. Derate linearly above 50°C case temperature at a rate of 0.9 mW/°C for the IB462.

Reference Voltage Circuit

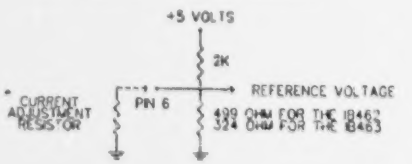


fig. 1

* See table 1 for current adjustment resistor values.

Optocoupler Input Circuit

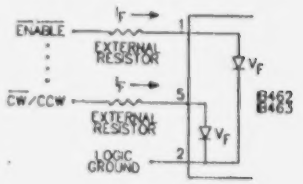


fig. 2

Timing Diagram

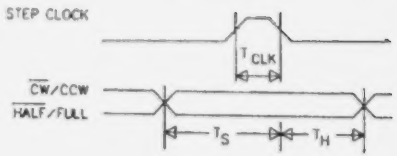


fig. 3

5 PIN DISCRIPTION = FUNCTION

PIN # 1: *ENABLE

Output enable input. When high (inactive) phase outputs are disabled.

PIN # 2: LOGIC GROUND

Logic signal common. This input is the return path for the logic signal inputs. To maintain isolation this signal should not be connected to pin # 7 (ground).

PIN # 3: *H/F

Half/Full step input. When low half step operation is selected. When high full step operation is selected. One-phase-on full step mode is obtained by selecting FULL when the IB462 and IB463 is at an even numbered state. Two-phase-on full step mode is set by selecting FULL when the IB462 and IB463 are at an odd numbered state. When power is applied to the IB462 and IB463 it automatically initializes to state 1.

PIN # 4: *CLK

Step clock input. An active high pulse on this input advances the motor one increment. The step occurs on the falling edge of this signal.

PIN # 5: *CW/CCW

Clockwise/ccunterclockwise direction input. Physical direction of the motor also depends on the connection of the windings. This input is syncronized internally and may be changed at any time.

PIN # 6: CURRENT ADJUST

Phase current adjustment input. A resistor is connected from this input to ground (pin 7 not pin 2) to adjust the phase current of the motor. If the resistor is omitted the current in each phase of the motor will be the maximum current of the driver (2 amps per phase for the IB462 and 3.5 amps per phase for the IB463).

Table 1 gives the resistor values for specified phase currents for the IB462 and IB463. Fig. 1 shows the resistor divider used to generate the reference voltage. The relationship between the reference voltage and phase current is given as;

IB462: current per phase(amps) = reference voltage(volts) X 2
IB463: current per phase(amps) = reference voltage(volts) X 5

Phase currents can be switched from one value to another by the use of mosfets (see application notes). A common use for this circuit is to lower the current in the motor when it is in a locked position. This will decrease the heat generated by the motor and drive along with the energy used by the system.

PIN # 7: GROUND

Supply voltage ground. This pin should not be connected to pin 2 (logic ground) if isolation is required.

PIN # 8: +V

Supply voltage input.

PIN # 9 & 10: ϕB

Phase B of the stepping motor is connected between pin 9 and pin 10.

PIN # 11 & 12: ϕA

Phase A of the stepping motor is connected between pin 11 and pin 12.

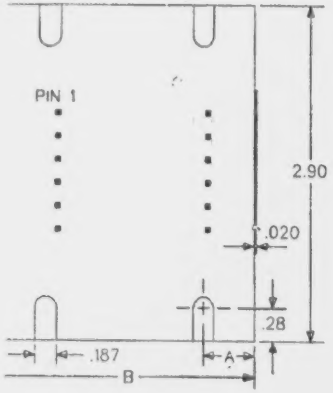
* If these inputs are left floating it will be equivalent to a logic 0 at the input.

6 THERMAL SPECIFICATIONS

Operating temperature	0 to +50 °C
Storage temperature	-40 to +125 °C
* Case temperature (max)	+80 °C

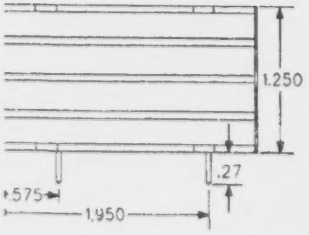
Note: External heat sink may be required above 1 amp per phase.

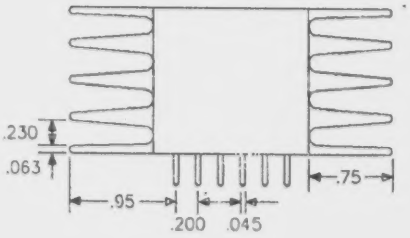
7 MECHANICAL SPECIFICATIONS



DIMENSIONS IN INCH.

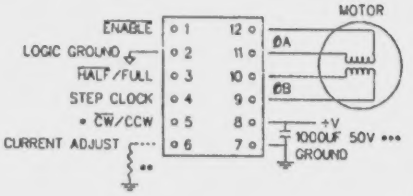
	IB462	IB463
A	.47	.59
B	2.37	2.95





8 APPLICATION INFORMATION

Stepping Motor Driver

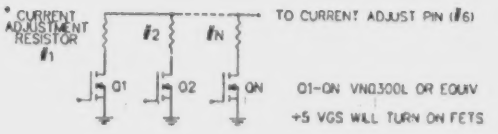


Note: Current limiting is required on all isolated inputs.

* Physical direction of the motor also depends on the connection of the motor windings.
** Needed only to reduce current. May be omitted for full scale current. See table 1 for current adjustment resistor values.
*** Capacitor should be placed as close to pins 7 and 8 as possible. (May be omitted if power supply filter capacitor is within 12 in. of drive).

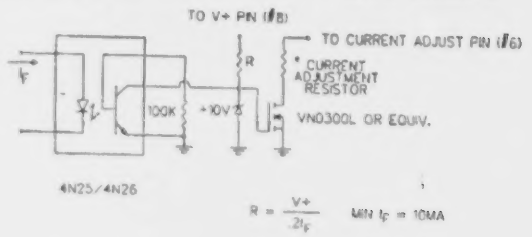
Switching Phase Currents

The circuit shown below may be used to switch from one current adjustment resistor to another, or to lower the current in the motor windings when the motor is in a locked position.



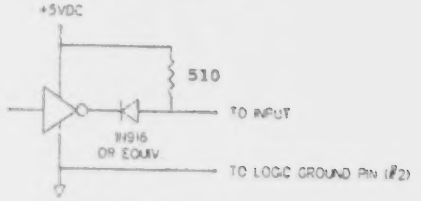
* See table 1 for current adjustment resistor values

Isolated Switching of Current Adjust Resistor

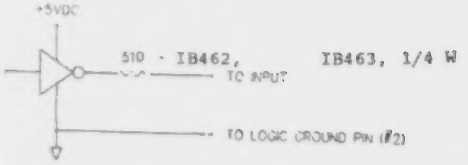


* See table 1 for current adjustment resistor values

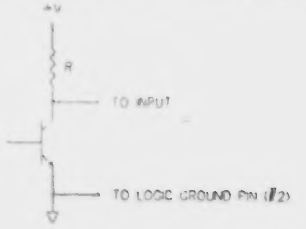
TTL Interface



74HC/54HC/74HCT/54HCT Interface



Open-Collector Interface



IB4621/IB463

*R	+V
510	5
1200	10
1500	12
2000	15
3000	24

*1/4 W

Current Resistor Values

Table 1

IB462			IB463		
Reference Voltage (volts)	Phase Current (amps)	Resistor Value (1% ohm)	Reference Voltage (volts)	Phase Current (amps)	Resistor Value (1% ohm)
.05	.1	21.0	.02	.1	8.25
.1	.2	44.2	.04	.2	16.9
.15	.3	69.8	.06	.3	26.1
.2	.4	100	.08	.4	36.1
.25	.5	133	.1	.5	46.4
.3	.6	169	.12	.6	57.6
.35	.7	215	.14	.7	69.8
.4	.8	267	.16	.8	82.5
.45	.9	324	.18	.9	97.6
.5	1.0	402	.2	1.0	110
.55	1.1	487	.22	1.1	127
.6	1.2	604	.24	1.2	147
.65	1.3	750	.26	1.3	165
.7	1.4	931	.28	1.4	187
.75	1.5	1210	.3	1.5	210
.8	1.6	1620	.32	1.6	237
.85	1.7	2260	.34	1.7	261
.9	1.8	3570	.36	1.8	294
.95	1.9	7680	.38	1.9	332
1.0	2.0	--	.4	2.0	374
			.42	2.1	422
			.44	2.2	475
			.46	2.3	536
			.48	2.4	604
			.5	2.5	698
			.52	2.6	806
			.54	2.7	931
			.56	2.8	1100
			.58	2.9	1330
			.6	3.0	1650
			.62	3.1	2150
			.64	3.2	2940
			.66	3.3	4530
			.68	3.4	9200
			.7	3.5	--

Low-Cost Stepping Motor Controllers offer Stepping Motor Control at an Economical Price

CyberResearch offers an economical motion controller which incorporates many high-performance features. Pulse, Direction, and Hold outputs are supplied for each axis of motor control. The Hold output line is active when the motor is stopped. Full-step operation is standard, while half-stepping control is possible using the user-definable digital output line (one per axis). Pulse rates of up to 240,000 steps per second are supported, making the **ESH 5000** well-suited to microstepping applications.

1, 2, & 3-Axis Versions

The low cost of this board makes it ideal for OEM applications. Available in 1, 2, or 3-axis versions, the **ESH 5000** can be purchased to exactly fit your needs. You only pay for the axes of motion you need to control.

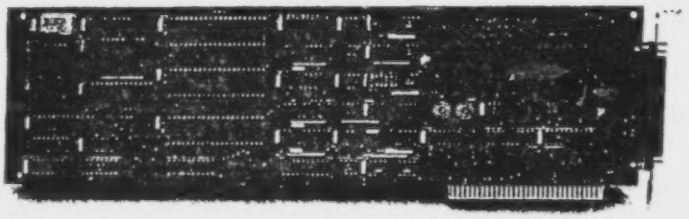
Great Flexibility for Motion Profiling

Dedicated PCL240K Intelligent Stepper Motor Controller chips (one per axis) enable programmable velocity profiling, including choice of direction. Users may select from four programming modes and eight operating modes. Up & down ramps can be programmed independently, and all parameters are changeable during motion.

Limit Lines Keep Your Motion in Check

The **ESH 5000** includes five digital input lines for limit switches. They are configured to be used as two stop limits, two acceleration limits, & one home limit. Connection of your drivers and limit switches to the **ESH 5000** is done via a single 37-pin D-connector. To simplify wiring, we offer a 37-pin screw terminal block with a six-foot cable.

ESH 5000 Stepping Motor Controller



Our new ESH 5000 series of Low-Cost Stepping Controllers are much easier to use than other Boards.

Optical Isolation Protects Your PC

The **ESH 5000** is designed to be totally optically-isolated from your motion system, protecting your PC from potential voltage spikes which could damage your computer. To isolate your system you must supply an external +5V source to power the output pulse, direction, & control lines. Our **INST 1140** power supply is quite sufficient for this task. If you are using optically-isolated drivers, such as those offered by CyberResearch, you can use your PC's power supply for your +5V source, while your chopper drivers provide the desired optical isolation for your system.

Stepping Motor Control Software

Each **ESH 5000** controller comes packaged with 3 software programs. **Profile** is an easy-to-use menu-driven motion profiling program. Designed to assist in the installation of your motion system, Profile allows you to quickly and easily put your motors through their expected movements. A set of advanced **software drivers** are included for use with Microsoft C (Ver. 5.1) and BASIC. Also included is a **command interpreter** to assist in designing your motion control software. Source code is included for the drivers and for the command interpreter.

Ordering Information:

#ESH 5001	1-Axis Low Cost Stepping Motor Controller Board with Software
#ESH 5002	2-Axis Low Cost Stepping Motor Controller Board with Software
#ESH 5003	3-Axis Low Cost Stepping Motor Controller Board with Software
#INST 339A	37-Pin Terminal Block with 6' Cable
#INST 1140	5V, 1A Wall-Plug Power Supply

High-Performance Bipolar Chopper Drivers

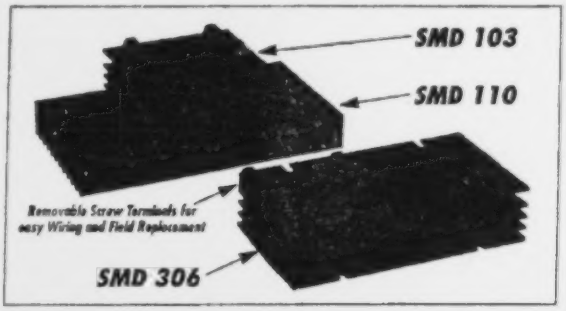
These are the low-cost drivers which have made L/R drivers obsolete. They offer the performance of chopper drivers at a price which is *lower* than competing L/R drivers. By using bi-polar chopper technology, they get your motors up to rated speed much more quickly and efficiently. (See page 121 for a more complete discussion of this technology.) Our **SMD 102** and **SMD 103** drivers are rated for up to 40,000 steps/second. Our **SMD 306** is rated in the ultra-fast range attained by few other stepping motor drivers on the market: 250,000 steps/second.

A 20 KHz chopping rate eliminates all audible noise, and all inputs are optically isolated for noise immunity. All models are electronically selectable between full and half step, letting you change on-the-fly without mechanical adjustments. These drivers pack a tremendous amount of power into a miniature package: the **SMD 306** puts out 1200W of power from a six cubic inch package. The heat sink (**#SMD 110**) is required to run an **SMD 102/103** driver near rated output without mounting it to a chassis.

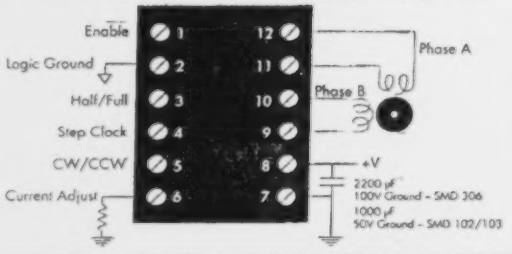
SMD 102 and **SMD 103** drivers make a good match with the lower current requirements of our Size 23, High-Speed Motors. The **SMD 306** can handle up to 6 Amps output current, making it a good match for the increased current requirements of our High-Torque, Size 34 Motors.

Ordering Information:

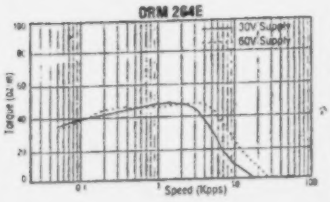
#SMD 102 40 Volt, 2 Amp Bi-Polar Chopper Driver
#SMD 103 40 Volt, 3.5 Amp Bi-Polar Chopper Driver
#SMD 110 Heat Sink for SMD 100 series Drivers
#SMD 306 100 Volt, 6 Amp Bi-Polar Chopper Driver

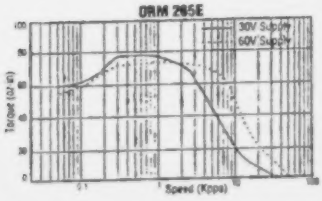


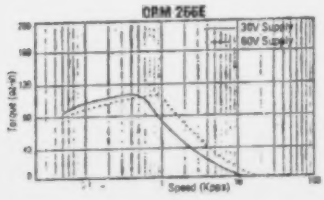
SMD 102/103/306 Wiring Diagram

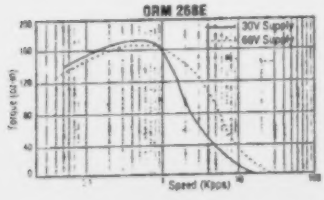


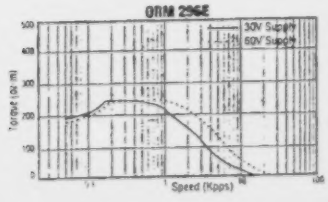
High Performance 8-Wire Stepping Motors

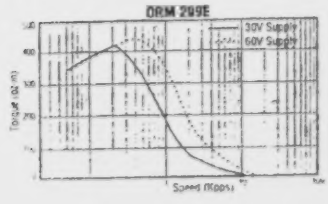




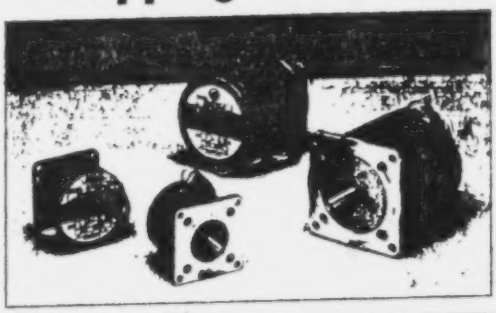








CyberResearch offers a variety of stepping motors to meet most experimental, commercial and industrial applications. They come in two standard sizes: NEMA standard size 23, and NEMA 34. All motors are single-shafted. In general, size 23 motors are well suited for high-speed applications where torque is a secondary consideration. Size 34 motors do not have the same speed ratings as some of the size 23 motors, but they can supply a great deal more torque at lower speeds.



All of these motors have a 1.8° step size, for 200 steps per revolution. In half step mode the step size becomes .9° for 400 steps/rev. These motors may also be used with our microstepping drivers which can produce 10 microsteps for each full step. Absolute positioning accuracy is rated at ±5% of one full step, or 1/2 of a microstep.

New 8-Wire Motors Offer Superior Performance

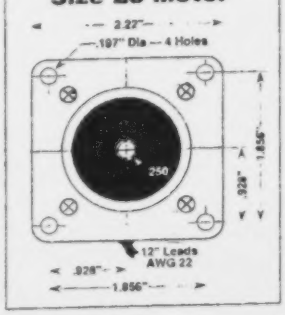
We have now started using 8-wire motors in place of the 6-wire motors we previously carried. What this means is that you can now run your motion system in **bipolar, parallel** mode. "Bipolar" refers to the fact that both phases of your motor are driven at the same time. (Refer to Tech Note on Page 121). "Parallel" refers to the fact that each winding is divided in half and the two halves are driven in parallel. This is more efficient than driving the full winding because the energy consumed by the winding increases as a square of its size. Parallel operation in effect gives you twice as many windings, each of which is smaller and more efficient. The performance of the motor is significantly improved. The speed/torque curves for our old 6-wire motors do not show nearly the performance that our new 8-wire motors offer.

Speed/Torque Curves Give You Crucial Information

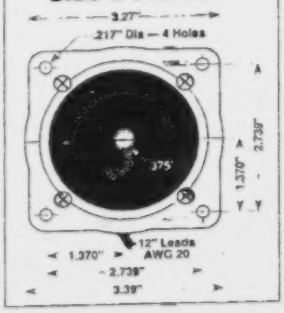
The accompanying speed/torque curves give you information which is vital to choosing the best motor for your application. The speed rating in the chart below, for example, tells you the speed at 20% of the holding torque. But the maximum speed at full torque might be much more crucial information. Our **ORM 299E** motor is rated at nearly twice the holding torque of the **ORM 296E**. Yet at speeds above 1,000 sps, the **ORM 296E** is capable of more torque than the **ORM 299E**. The curves also help you decide when a higher voltage supply will improve your performance. At lower speeds a 60V supply does not improve your torque capacity, but it does help you maintain torque levels at higher speeds. Our **ORM 299E**, for example, can put out twice as much torque at 1,000 sps when used with a 60V supply.

Be sure to check the torque scale at the left of the diagram. The scale varies for different motors. Also note that the speed scale on the x-axis is a logarithmic scale.

Size 23 Motor



Size 34 Motor

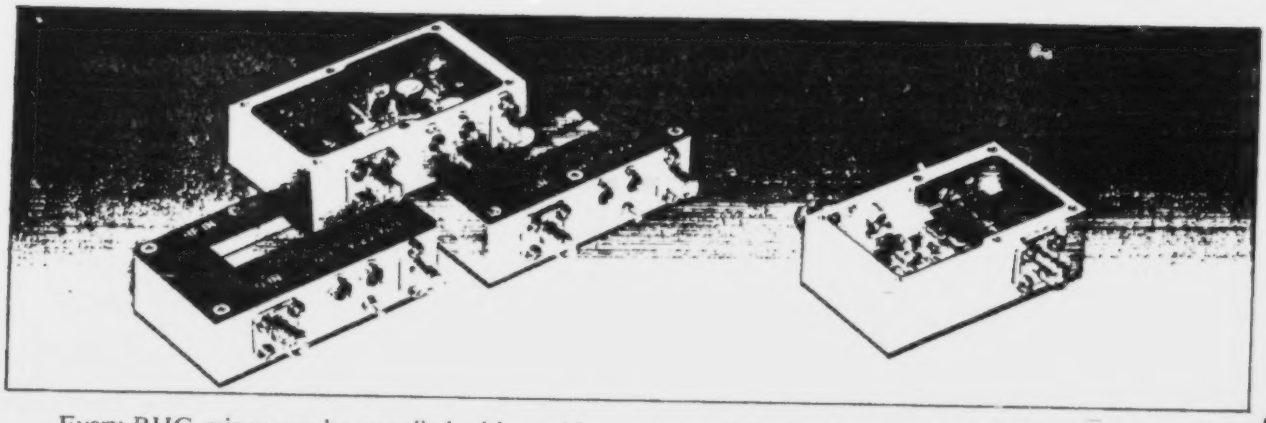


Part Number	Size	Holding Torque (oz-in)	Speed* (sps)	Current (A/phase) Series	Current (A/phase) Parallel	Voltage (VDC)	Inductance (mH/phase)	Suggested Chopper Driver
#ORM 264E	23	40.3	20,000	1.5	2.1	2.25	3.6	#SMD 103
#ORM 265E	23	58.3	30,000	2.6	3.7	1.85	30	#SMD 306
#ORM 266E	23	83.3	8,000	1.2	1.7	6.0	8	#SMD 102
#ORM 268E	23	125	12,000	2.3	3.3	3.9	32	#SMD 103
#ORM 296E	34	174	11,000	4.2	5.9	1.9	6	#SMD 306
#ORM 299E	34	306	6,000	4.0	5.6	3.0	30	#SMD 306

* Speed is specified for bi polar parallel operation with a 60V supply at 20% of Holding Torque See Speed/Torque curves at left for more detailed information.

Double Balanced MIC Mixer Preamps

■ Conventional and Microwave IF's ■ Gain and Phase Matched ■ 1 to 26 GHz



Every RHG mixer can be supplied with a wide range of IF preamplifiers. These IC preamps are mechanically and electrically integrated with the mixer to provide optimum noise figure. The use of a mixer/preamp assures this optimum noise performance, since the mixer/preamp interface is a key factor and is often improperly established when separate mixers and preamps are used.

The models listed on the following pages reflect many of the most requested combinations. If your needs are not met by a standard, we will be happy to provide a special unit on request.

OCTAVE MODELS

RF Band	Model Number	IF Freq/BW MHz	TYP N.F. (dB)	MAX N.F. (dB)	Price
L-Band 1.0-2.0 GHz	DM1-2/10A	60/10	7.0	8.0	$ 795
	DM1-2/10B	60/20	7.0	8.0	795
	DM1-2/10C	30/10	7.0	8.0	795
S-Band 2.0-4.0 GHz	DM2-4/10A	60/10	7.5	8.5	795
	DM2-4/10B	60/20	7.5	8.5	795
	DM2-4/10C	30/10	7.5	8.5	795
C-Band 4.0-8.0 GHz	DM4-8/10A	60/10	7.5	8.5	795
	DM4-8/10B	60/20	7.5	8.5	795
	DM4-8/10C	30/10	7.5	8.5	795
X-Band 8.0-12.0 GHz	DM8-12/10A	60/10	8.5	9.5	860
	DM8-12/10B	60/20	8.5	9.5	860
	DM8-12/10C	30/10	8.5	9.5	860
Ku-Band 12.0-18.0 GHz	DM12-18/10A	60/10	9.5	10.5	975
	DM12-18/10B	60/20	9.5	10.5	975
	DM12-18/10C	30/10	9.5	10.5	975
K-Band 18.0-26.0 GHz	DM18-26/10A	60/10	8.5	10.0	1195
	DM18-26/10B	60/20	8.5	10.0	1195
	DM18-26/10C	30/10	8.5	10.0	1195

SPECIAL PREAMPS:

To order, replace suffix with preamp type desired.

Preamp Type	Cent. Freq. (MHz)	Band-width (MHz min)	RF-IF Gain (dB min)	* Addit. N.F.	* Addit. Cost
10KK	10	2	25	0.5	$ 75
10LL	20	6	25	0.0	75
10D	70	10	25	0.0	75
10JJ	70	30	25	0.0	75
10BB	120	20	25	1.0	75
10DD	130	50	25	1.0	75
10HH	10 to	200	20	1.0	100

* Added to mixer preamp with 10A preamp type

SEE PAGES 69-71 FOR WAVEGUIDE MODELS

MULTIOCTAVE MODELS

RF Band	Model Number	IF Freq/BW MHz	N.F. (dB)	Price
0.1 to 1.0 GHz	DM0.1-1/10A	60/10	See	$ 920
	DM0.1-1/10B	60/20	Note 1	920
	DM0.1-1/10C	30/10	below	920
1.0 to 8.0 GHz	DM1-8/10A	60/10	See	860
	DM1-8/10B	60/20	Note 1	860
	DM1-8/10C	30/10	below	860
1.0 to 12.0 GHz	DM1-12/10A	60/10	See	940
	DM1-12/10B	60/20	Note 1	940
	DM1-12/10C	30/10	below	940
1.0 to 18.0 GHz	DM1-18/10A	60/10	See	1095
	DM1-18/10B	60/20	Note 1	1095
	DM1-18/10C	30/10	below	1095
1.0 to 26.0 GHz	DM1-26/10A	60/10	See	1255
	DM1-26/10B	60/20	Note 1	1255
	DM1-26/10C	30/10	below	1255

NOTES:

1. Noise figure of multioctave models is typically
   < 10 dB 0.1 to 1.0 GHz
   < 8 dB 1.0 to 8 GHz
   < 10 dB 8.0 to 26 GHz
2. VSWR: Typically 2.5:1
3. LO injection: +7 to +10 dBm
4. IF output capability: >0 dBm (all models)
5. LO-RF isolation: 20 dB
6. Impedance level: 50Ω, all ports
7. Gain (RF-IF): 25 dB (min) unless noted otherwise
8. Power: +12 VDC at 20 mA (typ).
   For +15 VDC add suffix "C" (no charge).
9. Most units available with biasable mixers for low LO power. Contact factory for details.
10. Weight: 55 g (1.9 oz) max.
11. Outline dimensions: See drawing on page 66.

(continued on next page) ►

ELECTRICAL TEST DATA

MODEL NUMBER DM8-12/10A

SERIAL NUMBER 31-561-7

DATE 12/19/89

DATA BY M.W

INPUT FREQUENCY RANGE:		8-12	GHz
IF CENTER FREQUENCY:		60	MHz
IF BANDWIDTH:		14	MHz
POWER GAIN (RF TO IF):		25	dB
TYPICAL LO POWER LEVEL:		+8.5	dBm
NOISE FIGURE:	8 GHz	6.5	dB
	10 GHz	7.3	dB
	12 GHz	7.7	dB
LO TO RF ISOLATION:	8 GHz	38	dB
	10 GHz	31	dB
	12 GHz	32	dB
LO INPUT IMPEDANCE:		50Ω	
SIGNAL INPUT IMPEDANCE:		50Ω	
IF OUTPUT IMPEDANCE:		50Ω	
POWER OUTPUT:		+8.6dbm@1db	
POWER DRAIN:		19.4 @ 12V	

COMMENTS: _____

MAXIMUM TORQUE FOR SMA CONNECTORS 7-10 INCH-POUNDS.
USE AMERICON 2098-5065 TORQUE WRENCH OR EQUAL

RHG ELECTRONICS LABORATORY, INC.
161 East Industry Court
Deer Park, New York 11729
(516) 242-1100

(FORM DM2)

RHG MIXER/AMPLIFIER

RECORD SHEET

DATE 6 Jan 94

PART NUMBER DMS-12/10A

SERIAL NUMBER 31-561-7

INPUT POWER 12 VDC @ 20.4 mA

TEST FREQUENCY 9300 MHz.

LO FREQUENCY 9240 MHz. @ +8 dBm

RF TO IF GAIN 24.8 dB

POWER OUTPUT 8.6 dBm. @ 1 dB COMP.

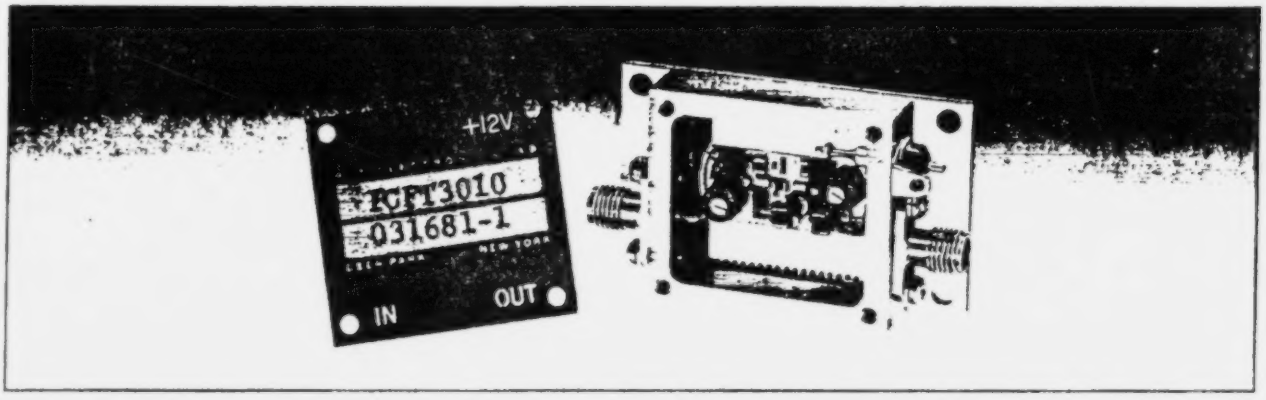
3 dB BANDWIDTH 13.94 MHz.

UNIT LOCATION VERT. CAL. REF. RCVR

RHG

Hybrid IC IF / RF / Microwave Preamplifiers

■ Low Noise ■ IC/MIC ■ Small Size



RHG offers a selection of low noise preamplifiers which operates at frequencies in the range of 5 to 2000 MHz. Most of the units listed are used in applications where the mixer employed is not integrated with an IF preamp, and the RHG unit can be connected to the mixer with a coaxial connection.

All the models offered can be used wherever a fixed amount of gain is desired. All units are unconditionally stable and relatively insensitive to source and load VSWR.

FIXED GAIN MODELS

Model No.	Center Freq. (MHz)	Bandwidth (MHz)	Power Gain (dB)	Noise Figure (dB)	Price
ICFT2006	20	6	30	2	$295
ICFT2106	21.4	6	30	2	295
ICFL3010	30	10	30	1.4	275
ICFT3010	30	10	30	2	225
ICFT6010	60	10	30	2	225
ICFT6020	60	20	30	2	225
ICFT6040	60	40	30	2	275
ICFT7030	70	30	30	2	275
ICFT12040	120	40	25	3.5	325
ICFT16050	160	50	25	3.5	325
ICFT300	10 to 300		25	2 (to 100 MHz) 4 (to 250 MHz)	325

Output Power (at 1 dB gain compression): 0 dBm

HIGH FREQUENCY MODELS

Model No.	Frequency	N.F. Typ. (dB)	N.F. Max. (dB)	Gain nominal (dB)	Price
ICFT5-500	5-500 MHz	2.0	3.5	25	$375
ICM0.5-1	0.5-1 GHz	3.5	4.5	18	400
ICM0.1-1	0.1-1 GHz	3.0	4.5	27	450

Output Power (at 1 dB gain compression): 0 dBm

HIGH POWER MODELS

Model No.	Center Freq. (MHz)	Bandwidth (MHz)	Power Gain (dB)	Noise Figure (dB)	Price
ICFH2006	20	6	25	3	$350
ICFH2106	21.4	6	25	3	350
ICFH3010	30	10	25	3	275
ICFH6010	60	10	25	3	275
ICFH6020	60	20	25	3	275
ICFH6040	60	40	25	3	350
ICFH7030	70	30	25	3	375
ICFH120LN	120	40	35	2.5	375
ICFH160LN	160	50	35	2.5	375

Output Power (at 1 dB gain compression): +15 dBm
(+13 dBm above 70 MHz)

VARIABLE GAIN MODELS

Model No.	Center Freq. (MHz)	Bandwidth (MHz)	Power Gain (dB)	Noise Figure (dB)	Price
ICFV2006	20	6	25	2.5	$350
ICFV2106	21.4	6	25	2.5	350
ICFV3010	30	10	25	2.5	275
ICFV6010	60	10	25	2.5	275
ICFV6020	60	20	25	2.5	275
ICFV6040	60	40	25	2.5	350
ICFV7030	70	30	25	2.5	375
ICFV12040	120	40	20	3.0	375
ICFV16060	160	60	20	3.5	375

Output Power (at 1 dB gain compression with 0 V gain control): +5 dBm
(Output power will be reduced as gain control increases)

NOTES:

1. Input/output impedance: 50Ω
2. Power: +12 VDC at 30 mA (60 mA for ICFH series).
   (For +15 VDC add suffix "C", no charge).
3. Gain control (ICFV only): 20 dB for 0 to −3 VDC
4. Connectors: SMA
5. Weight: 40 g (1.4 oz) max.

SPECIAL OPTIONS:

1. All units from 10 to 160 MHz are available in phase and gain tracking sets: ±2° and ±0.5 dB
   Variable gain models: ±5° *and* ±1 dB
   To order: add suffix "M", $75 per unit

(continued on next page) ►

ELECTRICAL TEST DATA

MODEL NUMBER ICFT6010 DATE 12-13-89

SERIAL NUMBER 31-561-11 DATA TAKEN BY JC

CENTER FREQUENCY:	60 MHZ
3 dB BANDWIDTH:	14 MHZ
____dB BANDWIDTH:	NA
NOISE FIGURE:	1.8dB
MAXIMUM POWER GAIN:	37dB
POWER OUTPUT:	0dBm @ 1dB comp.
POWER DRAIN:	+12VDC @ 16mA

COMMENTS:

RHG ELECTRONICS LABORATORY, INC.
161 East Industry Court
Deer Park, New York 11729
(516) 242-1100

APPENDIX B

VACP CONTROL SOFTWARE LISTING

```
10 ' BASIC PROGRAM TO CONTROL THE HP 8508A TEST INSTRUMENT AND
20 ' COLLECT THE DATA FROM THE VECTOR VOLTMETER, VIA THE HPIB
30 ' BY BOB MOORE, APPLIED SILICON INC. CANADA
40 ' 6 APRIL 1995
50 ' LATEST REVISION - 6 MAR. 96
60 ' ADDED STEPPER MOTOR CONTROL ON 16 AUGUST 1995 BY JOHN CURNOW
70 ' IT TAKES 54 SECONDS TO COLLECT THE DATA FOR THE 8 HORN POSITIONS
80 ' THIS PROGRAM IS CALLED VACPCAL3.BAS
90 ' REVISED 22 AUGUST 1995 TO COLLECT 64 AVERAGED SAMPLES IN V.V. AND
100 ' SAVE ONLY ONE DATA FILE, PLUS CREATED SUBROUTINES FOR MOTOR MOVEMENT
110 KEY OFF:CLS:CLOSE
120 PRINT"WELCOME TO THE VACP AUTOMATED CALIBRATION MEASUREMENT PROGRAM."
130 PRINT:PRINT"TURN OFF POWER TO THE VACP STEPPER MOTOR AND MANUALLY MOVE"
140 PRINT"THE HORN CARRIAGE TO THE UPPER MOST HORN POSITION,"
150 PRINT"THEN TURN ON THE POWER TO THE STEPPER MOTOR.":PRINT
160 INPUT"PRESS ENTER WHEN POSITIONED AND THE PIN IS REMOVED",C$
170 INPUT "WHAT IS THE DATA FILE NAME?",F$
180 LPRINT F$, DATE$, TIME$
190 LPRINT
200 OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
210 IOCTL#1,"BREAK"
220 PRINT#1,"RESET"
230 OPEN "\DEV\IEEEIN" FOR INPUT AS #2
240 PRINT#1,"FILL ERROR"
250 PRINT#1,"OUTPUT 08;*RST"
260 PRINT#1,"OUTPUT 08;*CLS"
270 PRINT#1,"OUTPUT 08;AVERAGE:COUNT 6"
280 PRINT#1,"OUTPUT 08;FORMAT LINEAR"
290 PRINT#1,"OUTPUT 08;TRIGGER:SOURCE BUS"
300 OPEN F$ FOR APPEND AS #3
310 FOR P=1 TO 8
320 PRINT"NOW COLLECTING DATA FOR THE HORN";P;"POSITION."
330 PRINT#1,"OUTPUT 08;MEASURE? AVOL,BVOL,PHASE"
340 PRINT#1,"ENTER 08 #33"
350 V$=INPUT$(33,#2)
360 AV=VAL(LEFT$(V$,6))*(10^VAL(MID$(V$,8,3)))
370 BV=VAL(MID$(V$,12,6))*(10^VAL(MID$(V$,19,3)))
380 PH=VAL(MID$(V$,23,6))*(10^VAL(MID$(V$,30,3)))
390 PRINT#3,P;AV;BV;PH
400 PRINT P,AV,BV,PH
410 LPRINT, P, AV,BV,PH
420 INPUT"PRESS ENTER WHEN READY TO MOVE HORN",C$
430 IF P<8 THEN GOSUB 520 ' SUBROUTINE TO MOVE CARRIAGE ONE HORN POSITION
```

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440 NEXT P
450 CLOSE #1,#2,#3
460 PRINT"CALIBRATION COMPLETE, NOW RETURNING TO START POSITION"
470 GOSUB 1250 ' SUBROUTINE TO RETURN CARRIAGE BACK TO START
480 PRINT"THE CARRIAGE IS NOW BACK AT THE START POSITION"
490 PRINT F$
500 END
510 ' SUBROUTINE TO MOVE ONE HORN POSITION DOWN
520 OUT 768, 32 ' ACCESS RESET LATCH
530 OUT 769, 0 ' PERFORM HARD RESET
540 OUT 768, 32 ' ACCESS RESET LATCH
550 OUT 769, 1 ' RESET AXIS A ONLY
560 OUT 768, 0 ' ACCESS AXIS A COMMAND BUFFER
570 OUT 769, 8 ' PERFORM SOFT RESET BEFORE MOVING
580 OUT 768, 0 ' ACCESS COMMAND BUFFER
590 OUT 769, 78 ' DOWN DIRECTION, PRESET RAMP-DOWN MODE
600 OUT 768, 0
610 OUT 769,128 ' POINT TO R0 REGISTER
620 OUT 768, 1 ' ENABLE LOADING OF LOW BYTE
630 OUT 769, 53 ' FOR VACP ONE POSITION IS 4917 STEPS=1335 HEX, 35H=53DEC
640 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
650 OUT 769, 19 ' 13HEX=19DEC
660 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
670 OUT 769, 0
680 OUT 768, 0
690 OUT 769,129 ' POINT TO R1 REGISTER
700 OUT 768, 1
710 OUT 769,200 ' SET LOW SPEED TO 200 PPS
720 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
730 OUT 769, 0
740 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
750 OUT 769, 0
760 OUT 768, 0
770 OUT 769,130 ' POINT TO R2 REGISTER
780 OUT 768, 1
790 OUT 769,184 ' SET HIGH SPEED TO 3000 PPS=BB8HEX, B8=184DEC
800 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
810 OUT 769, 11
820 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
830 OUT 769, 0
840 OUT 768, 0
850 OUT 769,132 ' POINT TO R4 REGISTER FOR ACCELERATION
860 OUT 768, 1
```

```
870 OUT 769,196 ' SET ACCELERATION TO 2000 PPS/S, SO R4 = 2500DEC
880 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
890 OUT 769, 9 ' C4HEX=196DEC
900 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
910 OUT 769, 0
920 OUT 768, 0
930 OUT 769,133 ' POINT TO R5 REGISTER FOR DECELERATION
940 OUT 768, 1
950 OUT 769,196 ' SET DECELERATION TO 1000 PPS/S, SO R5 MUST BE
960 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
970 OUT 769, 9 ' 13HEX=19DEC
980 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
990 OUT 769, 0
1000 OUT 768, 0
1010 OUT 769,134 ' POINT TO R6 REGISTER FOR RAMPING DOWN POINT
1020 OUT 768, 1
1030 OUT 769,204 ' SET TO 2252DEC=8CCHEX, CCHEX=204DEC
1040 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
1050 OUT 769, 8
1060 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
1070 OUT 769, 0
1080 OUT 768, 0
1090 OUT 769,135 ' POINT TO R7 REGISTER FOR RATE MULTIPLIER
1100 OUT 768, 1
1110 OUT 769, 98 ' SET TO 610DEC=262HEX, 62HEX=98DEC
1120 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
1130 OUT 769, 2
1140 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
1150 OUT 769, 0
1160 OUT 768, 0
1170 OUT 769,192 ' ENABLE RAMP UP/DOWN AS OUTPUT MODE SELECTION
1180 OUT 768, 0
1190 OUT 769, 21 ' START MOTION WITH FH1 HIGH SPEED
1200 OUT 768, 0
1210 A=INP(769)  ' A IS THE CONTENT OF THE STATUS PORT
1220 A=A AND 64  ' MASK PULSE OUTPUT ACTIVE BIT
1230 IF A>0 THEN GOTO 1200 ' WAIT UNTIL THE PULSE OUTPUT IS INACTIVE
1240 RETURN
1250 ' SUBROUTINE TO MOVE CARRIAGE FROM LOWEST POSITION BACK TO START
1260 OUT 768, 32 ' ACCESS RESET LATCH
1270 OUT 769, 0 ' PERFORM HARD RESET
1280 OUT 768, 32 ' ACCESS RESET LATCH
1290 OUT 769, 1 ' RESET AXIS A ONLY
```

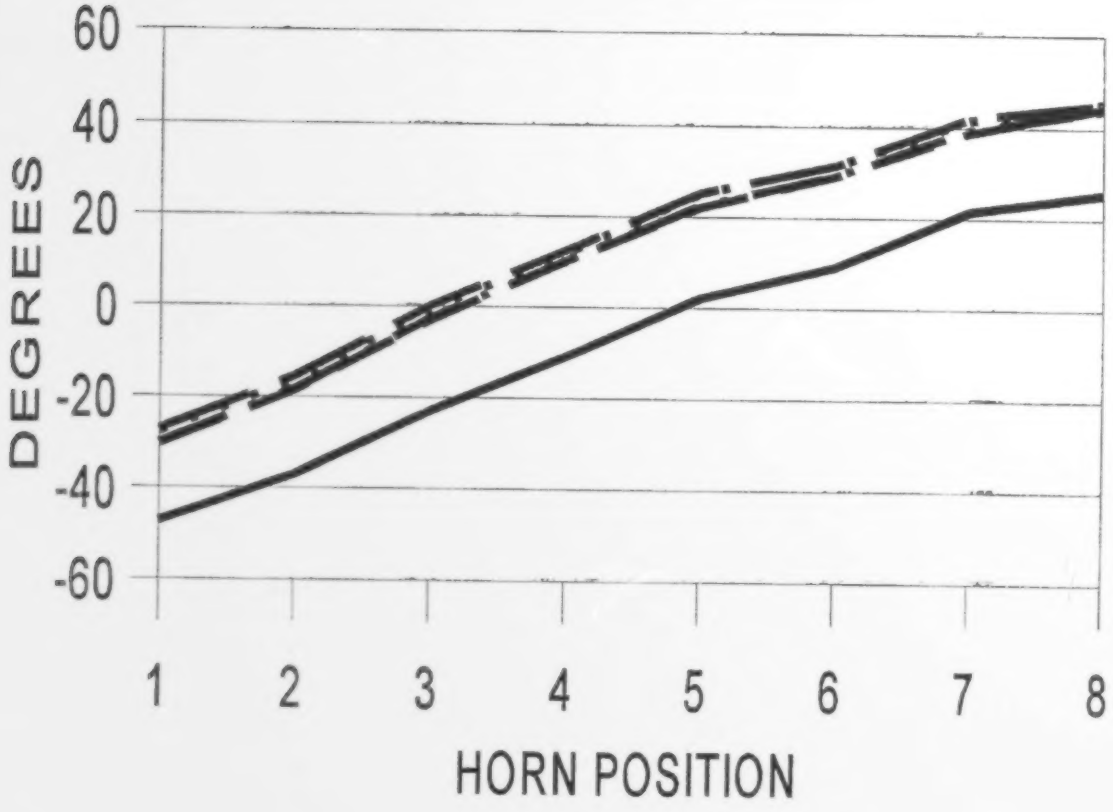
```
1300 OUT 768,  0 ' ACCESS AXIS A COMMAND BUFFER
1310 OUT 769,  8 ' PERFORM SOFT RESET BEFORE MOVING
1320 OUT 768,  0 ' ACCESS COMMAND BUFFER
1330 OUT 769, 70 ' UP DIRECTION, PRESET RAMP-DOWN MODE
1340 OUT 768,  0
1350 OUT 769,128 ' POINT TO R0 REGISTER
1360 OUT 768,  1 ' ENABLE LOADING OF LOW BYTE
1370 OUT 769,143 ' FOR VACP 7 POSITIONS ARE 34447 STEPS=868F HEX, 8FH=143DEC
1380 OUT 768,  2 ' ENABLE LOADING OF MIDDLE BYTE
1390 OUT 769,134 ' 86HE0X=134DEC
1400 OUT 768,  3 ' ENABLE LOADING OF UPPER BYTE
1410 OUT 769,  0
1420 OUT 768,  0
1430 OUT 769,129 ' POINT TO R1 REGISTER
1440 OUT 768,  1
1450 OUT 769,200 ' SET LOW SPEED TO 200 PPS
1460 OUT 768,  2 ' ENABLE LOADING OF MIDDLE BYTE
1470 OUT 769,  0
1480 OUT 768,  3 ' ENABLE LOADING OF UPPER BYTE
1490 OUT 769,  0
1500 OUT 768,  0
1510 OUT 769,130 ' POINT TO R2 REGISTER
1520 OUT 768,  1
1530 OUT 769,184 ' SET HIGH SPEED TO 3000 PPS=BB8HEX, B8=184DEC
1540 OUT 768,  2 ' ENABLE LOADING OF MIDDLE BYTE
1550 OUT 769, 11
1560 OUT 768,  3 ' ENABLE LOADING OF UPPER BYTE
1570 OUT 769,  0
1580 OUT 768,  0
1590 OUT 769,132 ' POINT TO R4 REGISTER FOR ACCELERATION
1600 OUT 768,  1
1610 OUT 769,196 ' SET ACCELERATION TO 2000 PPS/S, SO R4 = 2500DEC
1620 OUT 768,  2 ' ENABLE LOADING OF MIDDLE BYTE
1630 OUT 769,  9 ' C4HEX=196DEC
1640 OUT 768,  3 ' ENABLE LOADING OF UPPER BYTE
1650 OUT 769,  0
1660 OUT 768,  0
1670 OUT 769,133 ' POINT TO R5 REGISTER FOR DECELERATION
1680 OUT 768,  1
1690 OUT 769,196 ' SET DECELERATION TO 1000 PPS/S, SO R5 MUST BE
1700 OUT 768,  2 ' ENABLE LOADING OF MIDDLE BYTE
1710 OUT 769,  9 ' 13HEX=19DEC
1720 OUT 768,  3 ' ENABLE LOADING OF UPPER BYTE
```

```
1730 OUT 769, 0
1740 OUT 768, 0
1750 OUT 769,134 ' POINT TO R6 REGISTER FOR RAMPING DOWN POINT
1760 OUT 768, 1
1770 OUT 769,204 ' SET TO 2252DEC=8CCHEX, CCHEX=204DEC
1780 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
1790 OUT 769, 8
1800 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
1810 OUT 769, 0
1820 OUT 768, 0
1830 OUT 769,135 ' POINT TO R7 REGISTER FOR RATE MULTIPLIER
1840 OUT 768, 1
1850 OUT 769, 98 ' SET TO 610DEC=262HEX, 62HEX=98DEC
1860 OUT 768, 2 ' ENABLE LOADING OF MIDDLE BYTE
1870 OUT 769, 2
1880 OUT 768, 3 ' ENABLE LOADING OF UPPER BYTE
1890 OUT 769, 0
1900 OUT 768, 0
1910 OUT 769,192 ' ENABLE RAMP UP/DOWN AS OUTPUT MODE SELECTION
1920 OUT 768, 0
1930 OUT 769, 21 ' START MOTION WITH FH1 HIGH SPEED
1940 OUT 768, 0
1950 A=INP(769)  ' A IS THE CONTENT OF THE STATUS PORT
1960 A=A AND 64  ' MASK PULSE OUTPUT ACTIVE BIT
1970 IF A>0 THEN GOTO 1940 ' WAIT UNTIL THE PULSE OUTPUT IS INACTIVE
1980 RETURN
```

APPENDIX C

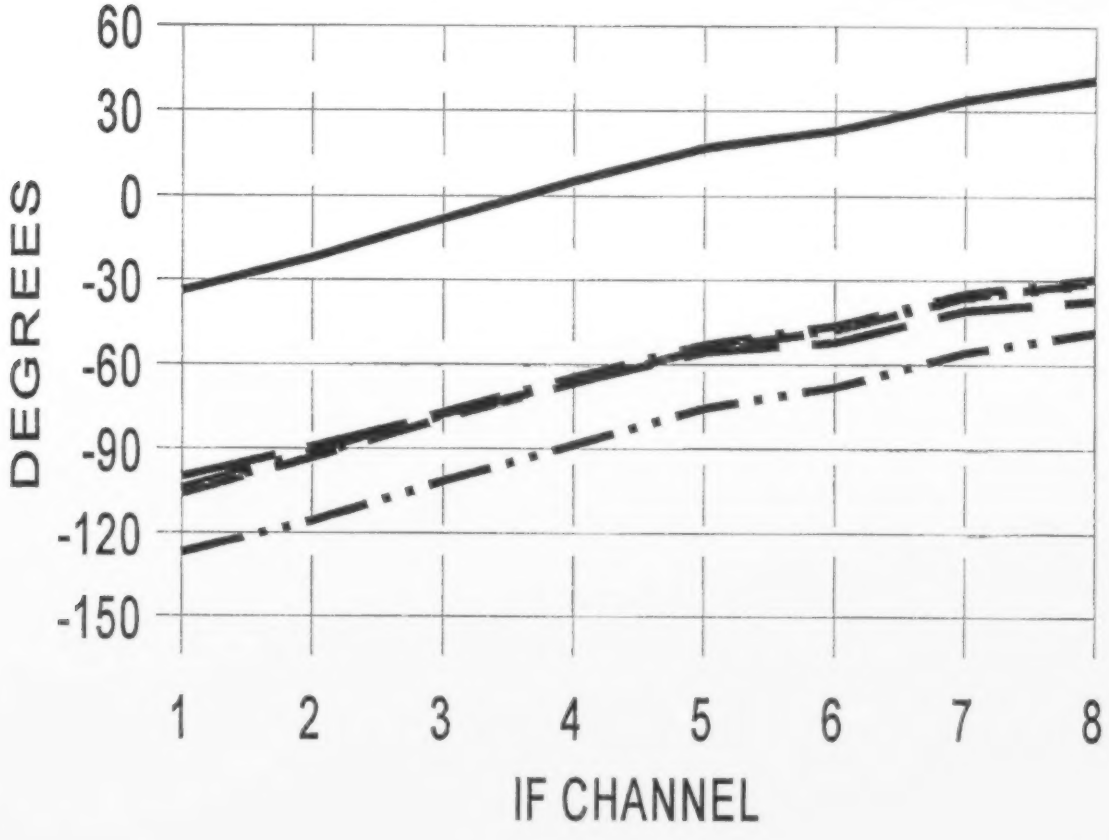
SAMPLE VACP PHASE PLOTS

VP IF PHASE



M07VP-A
M07VP-B
M07VP-C
M07VP-D
M07VP-E

VP 60 MHZ IF PHASE



M15VP-B

M18VP-A

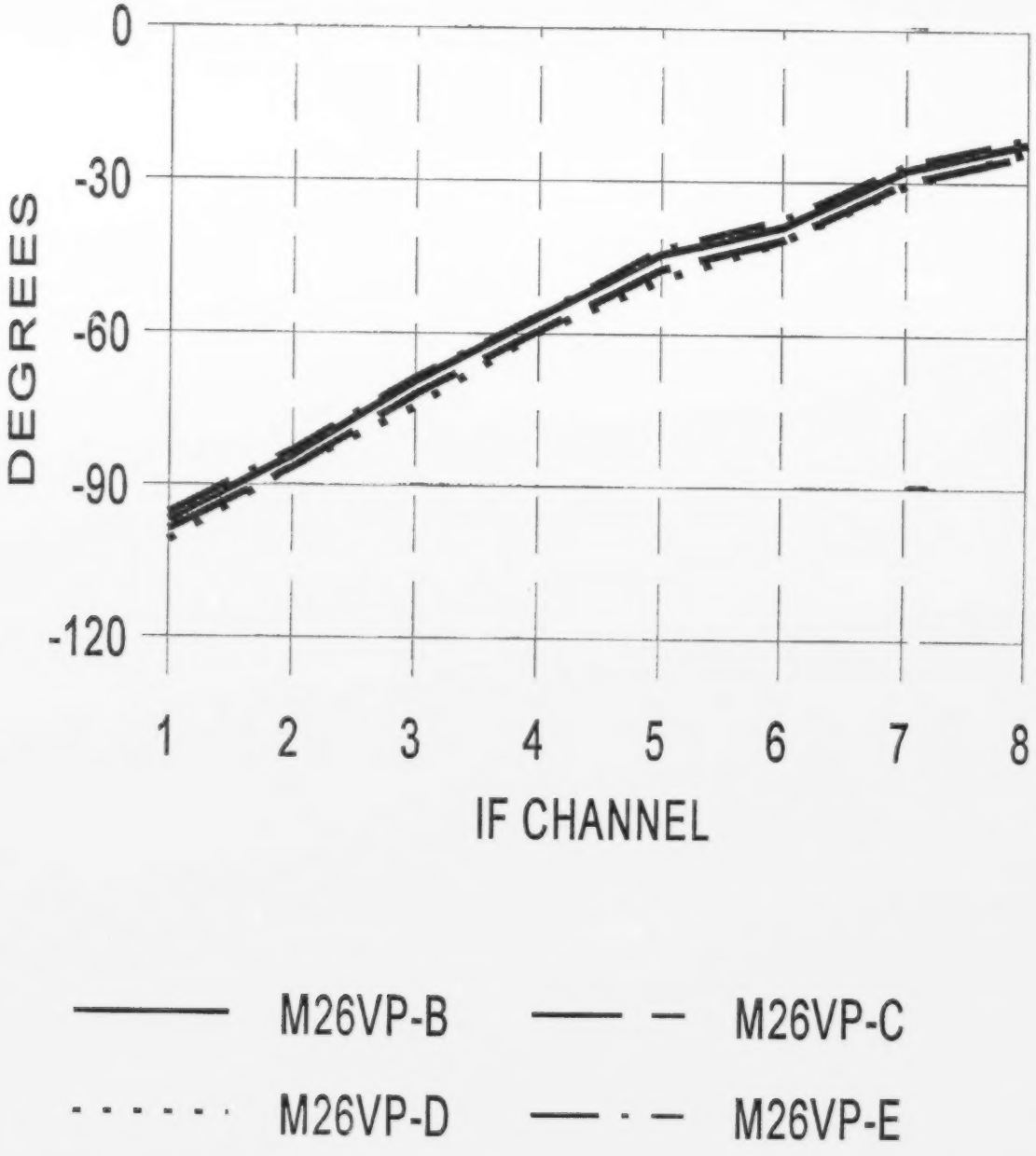
M21VP-B

M21VP-C

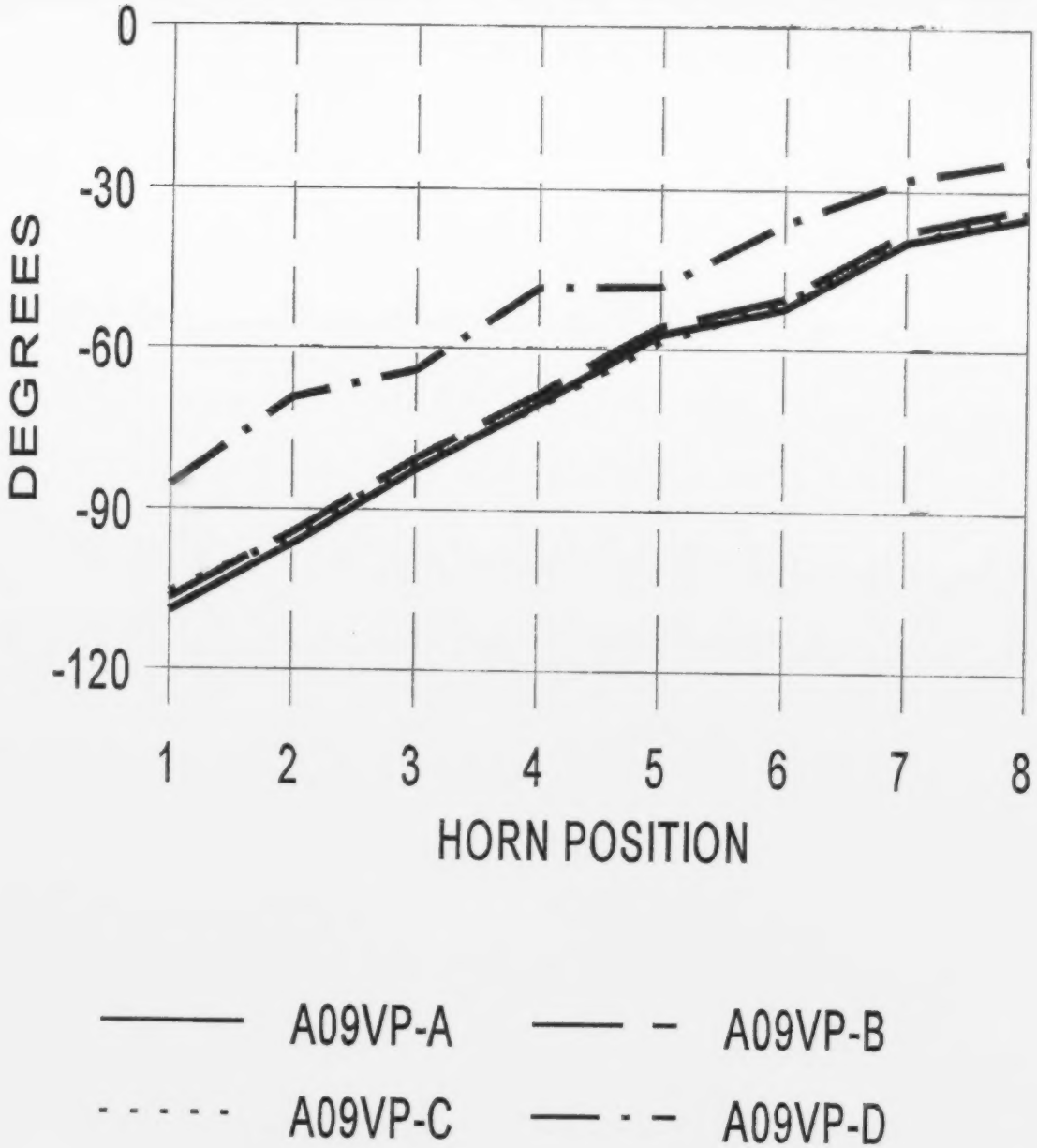
M21VP-D

M22VP-A

VP 60 MHZ IF PHASE



VP IF PHASE


0
-30
-60
-90
-120
DEGREES
1
2
3
4
5
6
7
8
HORN POSITION
A09VP-A
A09VP-B
A09VP-C
A09VP-D

APPENDIX D

VACP INTERCONNECTIONS

UNIT NUMBER	27
NAME	**VERTICAL ARRAY CALIBRATION PROFILER**
LOCATION	Front end rack, attached to vertical array. Mixer box on rear vertical array plate. Stepper motor driver (IB463) has temporary position on rack and driver card is in personal computer in the tall bay or EARS lab.
TOTAL CONNECTORS	8, plus hard wired connections to SMD103
NUMBER OF PAGES	2
LAST UPDATED ON	5 December 1995

27J1 MSBP type, Bendix part number PT02E-8-4P
MOUNTED ON THE MIXER BOX

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	IN	+12 VDC POWER FOR MIXER	+12 VDC	3J5-A
B	IN	GROUND	GROUND	3J5-B
C	---	Not used		-----
D	---	Not used		-----

CONNECTORS 27J2, 27J3 AND 27J4 ARE MOUNTED ON THE MIXER BOX

CONN. NUMB.	TYPE	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
27J2	SMA	IN	LOCAL OSCILLATOR FOR MIXER	+8 dBm	5J7
27J3	SMA	IN	MIXER RF INPUT FROM RECEIVE HORN	VARIABLE	27J8
27J4	BNC	OUT	MIXER OUTPUT TO VECTOR VOLTMETER	VARIABLE	INST.

27J5 MSBP type, Bendix part number PT02E-12-10P
MOUNTED ON STEPPER MOTOR/GEAR BOX AT TOP OF DRIVE BELT

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	IN	MOTOR PHASE A, HARD-WIRED TO IB463	0/+21 VDC	IB463
B	IN	MOTOR PHASE $\overline{A}$, HARD-WIRED TO IB463	0/+21 VDC	IB463
C	IN	MOTOR PHASE $\overline{B}$, HARD-WIRED TO IB463	0/+21 VDC	IB463
D	IN	MOTOR PHASE B, HARD-WIRED TO IB463	0/+21 VDC	IB463
E-K	---	Not Used		-----

UNIT 27, VERTICAL ARRAY CALIBRATION PROFILER, page 2 of 2

27J6 MSBS type, Bendix part number PT06E-8-4S POSITIONED IN-LINE BETWEEN LIMIT SWITCHES AND TE5000 DRIVER CARD. HARD-WIRED TO LIMIT SWITCHES.

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	OUT	UPPER LIMIT SWITCH (+ DIRECTION)	TTL	27J7-4
B	OUT	UPPER LIMIT SWITCH RETURN LINE	GROUND	27J7-25
C	OUT	LOWER LIMIT SWITCH (- DIRECTION)	TTL	27J7-6
D	OUT	LOWER LIMIT SWITCH RETURN LINE	GROUND	27J7-25

27J7 'C' SIZE D-SHELL WITH 37 SOCKETS, SULLINS P/N DZF37PDAI MOUNTED ON REAR OF TE5000 DRIVER CARD IN PERSONAL COMPUTER

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
1	IN	+5 VDC SUPPLY FROM 7805 IC ON IB463	+5 VDC	IB463
2	OUT	MOTOR DIRECTION, $\overline{CW}$/CCW ON IB463	TTL	IB463
3	OUT	HALF/FULL STEP TO $\overline{H}$/F ON IB463	TTL	IB463
4	IN	+ DIRECTION (UP) END LIMIT	TTL	27J6-A
5	---	Not Used		-----
6	IN	- DIRECTION (DOWN) END LIMIT	TTL	27J6-C
7-19	---	Not Used		-----
20	OUT	PULSE OUTPUT TO STEP CLOCK ON IB463	0/+21 VDC	IB463
21	---	Not Used		-----
22	---	Not Used		-----
23	---	Not Used		-----
24	---	Not Used		-----
25	OUT	GROUND TO GROUND PIN ON IB463	GROUND	IB463
25	OUT	UPPER LIMIT SWITCH RETURN LINE	GROUND	27J6-B
25	OUT	LOWER LIMIT SWITCH RETURN LINE	GROUND	27J6-D
26 TO 37		Not Used		----

CONNECTORS 27J8 IS MOUNTED ON THE RECEIVE HORN TRANSITION

CONN. NUMB.	TYPE	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
27J8	SMA	OUT	RECEIVED RF FROM REMOTE SOURCE	VARIABLE	27J3

NOTE - THE IB463 IS THE MODEL NUMBER OF THE STEPPER MOTOR DRIVER FOR THE VACP. IT HAS HARD WIRED CONNECTIONS ONLY AND IS PLACED ON THE FRONT END RACK ONLY WHEN IT IS NEEDED.

There are several common types of connectors used throughout the EARS. To reduce the volume of text and to make the tables easier to read, the most common connectors are described and acronyms assigned to them. The most common type of connector used for DC supply voltages and control signals is the military type circular multi-pin connector. This style of connector can either have threads or a bayonet mechanical connection. It can have almost any number of connections and can have pins or pin sockets. By convention, the connector that carries the live signals, such as DC voltages, has the sockets, or is the female type.

The coaxial connections are usually made using one of two common connectors. The BNC jack (female) chassis, or bulkhead, connector is very common. It uses a bayonet mount and mates with the plug (male) connector on the coaxial cable. It is used when the frequency is below 4 GHz and quick connections are required. The SMA connector is smaller than the BNC connector and is threaded. It is used for higher frequency signals such as the X-band signals. The chassis SMA connector is always a jack (female) type. The following acronyms are used for the most common types of connectors.

Acronym	Connector Description
MSBS	circular military style connector, bayonet with sockets, bulkhead mount
MSBP	circular military style connector, bayonet with pins, bulkhead mount
MSTS	circular military style connector, threaded with sockets, bulkhead mount
MSTP	circular military style connector, threaded with pins, bulkhead mount
BNC	BNC type connector, jack bulkhead mount
SMA	SMA type connector, jack bulkhead mount

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ABBREVIATIONS

CCM	Calibration Control Mechanism
CRC	Communications Research Center
dB	decibel
DREO	Defence Research Establishment Ottawa
EARS	Experimental Array Radar System
ELAT	Experimental Low Angle Tracking
GPIB	General Purpose Interface Bus
IF	Intermediate Frequency
LNA	Low Noise Amplifier
LO	Local Oscillator
NF	Noise Figure
PRF	Pulse Repetition Frequency
RF	Radio Frequency
SLC	Side Lobe Canceller
TTL	Transistor Transistor Logic
TWTA	Travelling Wave Tube Amplifier
VACP	Vertical Array Calibration Profiler
VDC	Volts Direct Current
VSWR	Voltage Standing Wave Ratio

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This document presents a detailed hardware and operational description of the Vertical Array Calibration Profiler. This apparatus is used to calibrate the vertical array. The vertical array is one of two eight element arrays in the Experimental Array Radar System (EARS). It has eight standard gain horns oriented in a vertical line using horizontal polarization. This report presents a short description of the EARS and how the vertical array and VACP are used in the system. The VACP is described in detail, beginning with a general description and continuing with more detailed information.

This document was prepared under task 6.3 of contract number W7714-5-9868. It covers a gap in the system documentation. The VACP was designed and built by the Communications Research Center (CRC) under guidance from Applied Silicon personnel. There has been no previous formal documentation written about it. The calibration procedure for the vertical array is described, along with the use of the VACP as part of this procedure. Preliminary calibrations of the vertical array and the calibration software used are also described.

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TTL	Transistor Transistor Logic
TWTA	Travelling Wave Tube Amplifier
VACP	Vertical Array Calibration Profiler
VDC	Volts Direct Current
VSWR	Voltage Standing Wave Ratio

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